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Health Aspects

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OHIO RIVER BASIN ENERGY STUDY:
HEALTH ASPECTS

By

Maurice A. Shapiro
Attila A. Sooky

Graduate School of Public Health
University of Pittsburgh
Pittsburgh, Pennsylvania 15261

Prepared for

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Project Officer

Lowell Smith
Office of Environmental Engineering and Technology
Office of Research and Development
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16. ABSTRACT

This report was prepared as part of the Ohio River Basin Energy Study (ORBES), a multi-disciplinary program supported by the Environmental Protection Agency. It attempts to establish health damage functions for energy resource extraction, conversion (i.e., burning of coal to produce electricity), and power transmission in the ORBES region, which consists of all of Kentucky, most of West Virginia, and substantial portions of Illinois, Indiana, Ohio and Pennsylvania. Also covered in the report are patterns of mortality and health services in the study region and baseline data on health aspects of coal and uranium extraction, of coal-fired and nuclear-fueled electrical generation, of transportation and electrical transmission.

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FOREWORD

The Ohio River Basin Energy Study (ORBES) is an interdisciplinary, multi-university inquiry into the environmental, economic, and social impacts of energy facility development in a major portion of the Ohio River Basin. The study was initiated by the U.S. Environmental Protection Agency in 1976 in response to a directive from the U.S. Senate Appropriations Committee.

Most of the ORBES research was conducted by a group of faculty members at the University of Illinois, Indiana University, the University of Kentucky, the University of Louisville, The Ohio State University, the University of Pittsburgh, Purdue University, and West Virginia University. In a few instances, the necessary expertise was found at other universities or independent research organizations.

This report is one of a series produced in support of the overall ORBES assessment. For a summary of the entire study, see Ohio River Basin Energy Study (ORBES): Main Report, by the ORBES Core Team, also being published by the U.S. Environmental Protection Agency.

PREFACE

Establishing health damage functions for energy resource extraction, transportation, conversion (i.e., burning of coal to produce electricity, converting coal to synthetic liquid and gaseous fuels, or the operation of nuclear reactors) and power transmission is a difficult task. To attempt to do justice to the ORBES mandate we undertook a series of studies and investigations to which a number of individuals contributed significantly. Dr. Edward P. Radford completed a special study "Impacts on Human Health From the Coal and Nuclear Fuel Cycles and Other Technologies Associated With Electric Power Generation and Transmission." Dr. Radford also organized the Symposium on Energy and Human Health - Human Costs of Electric Power Generation from which much necessary information was gained. The proceedings of this symposium were published as an EPA report - (EPA 600/9-80-030 May, 1980).

Many have worked to assure that the ORBES mission was completed and our sincere thanks are due to: Sue Little, George Kay working as members of the staff, Joseph Bern, Richard Burgess and Donald Gibala, James E. Nesbitt and Samuel C. Morris each contributed of their special knowledge. Finally, to our very patient secretaries who typed all of the drafts and numerous tables Gloria Ramsden, Lynette Bethune and Phyllis Chavlovich, we owe special thanks.

Maurice A. Shapiro
Attila A. Sooky

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1. INTRODUCTION

The Ohio River Basin Energy Study (ORBES) began in the fall of 1976 when the U.S. Environmental Protection Agency (EPA) awarded grants to several universities for an assessment of the potential environmental, social and economic impacts of a proposed concentration of electric generating power plants in a portion of the basin. Later the study was expanded to include the whole Ohio River basin.

In 1975, the U.S. Senate Appropriations Committee had directed EPA to carry out such a study. It was not long after the Arab oil embargo (1972-73), and a number of electric utilities had announced plans to construct additional generating units in the Ohio River Basin and in nearby areas that share its fuel supply. The Ohio River basin offers electric utilities and related industries some of the nation's most suitable power plant sites- within easy reach of coalfields, plus abundant water for cooling. Regional waterways also provide good fuel transportation routes. Finally, there are sparsely populated areas of basin land where plants could be constructed displacing fewer residents than they would in urban areas.

In an effort to identify the implications of locating future energy conversion facilities in the lower part of the Ohio River basin, the Senate Appropriations Committee directed EPA to conduct a study, "comprehensive in scope, investigating the impacts from air, water, and

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solid residues on the natural environment and residents of the region. The study should also take into account the availability of coal and other energy sources in this region."

One of the most perplexing dilemmas of our industrialized and electrified society is the accommodation of the often conflicting goals of maintaining a healthful environment while retaining the several benefits of modern technology. The benefits of generated electricity may be measured by the number of toasters or air conditioners we are able to operate, or by the number of jobs an electricity utilizing industry sustains. However, these are blessings which bring with them often less visible costs which produce environmental and occupational health damaging conditions such as: air and water pollution, released ionizing radiation, toxic compounds in air, water and food, noise pollution and accidental injury and death. These are part of the price we are now paying for the changes that, through the years, have been wrought in our physical environment in general and that of the ORBES region in particular. Considering these disbenefits, it is well to remember historical precedents. The social reform and cleaning of the physical environment which followed in reaction to the conditions attending the Industrial Revolution, had a major impact upon the eventual control of communicable and infectious disease. In terms of speed and extent of control, the greatest strides in the conquest of these diseases were made in response to the social and economic reforms that followed industrialization. However, the cancers, vascular disorders and mental diseases which were not affected by the "sanitary movement" remain the great health problems of our age and their solution is still a hope.

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The public and occupational health implications of current and possible energy futures of the ORBES region constitute an important aspect of the entire project. Senator Byah in his address to the ORBES-sponsored Symposium on Energy and Human Health (1) described this fact as follows.

"I think we have to do a better job of articulating the health realities, not just the immediate cost of environment as they damage health, but the long range relationship of environment to health. Secondly, I think we need to have a better assessment of economic consequences, real economic consequences, real economic consequences - how they play on health, what the dimensions of the health laws will be. If you are really going to be able to weigh this off we have to have all those facts so we can make intelligent decisions. I think it is possible to do that and ORBES is going to be very helpful to us. But this is a critical kind of decision that we just have to be prepared to make."

The following public and occupational health baselines are built upon understanding derived from current knowledge of cause and effect relationships as they relate to accidental injury and death. However, the definitive health consequences of chronic, relatively low level exposure to the several environmental contaminants resulting from the generation of electricity remain unresolved. In particular, major questions remain as to the extent of health damages resulting from contaminants such as sulfur compounds, nitrogen compounds and particulates derived from the combustion of fossil fuels and the ionizing radiation exposures from the operation of the nuclear fuel cycle to generate electricity.

The study and evaluation of the damage or human health costs of current and future electricity generation present a wide spectrum of difficulty.

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The enumeration of accidental injuries and death, despite some tendency to underreport, is probably the most accurate and complete of the several health damages. Therefore, it is possible to project their future costs. At the other end of the spectrum, environmental hazards are among the most intractable health problems to investigate epidemiologically and air pollution in particular has been found to be very complex and elusive.

It is difficult to evaluate the contribution of individual contaminants to health damage or the mechanisms by which they do so. In past investigations it has been possible to distinguish between the following three major types of health reactions to air pollutants.

A-Acute effects in healthy individuals. These are most vividly illustrated by the results of major episodes of increases in pollution levels such as occurred in Donora, Pennsylvania in 1948 and London in 1952 and 1960.

B-Exacerbation of pre-existing diseases. These are observed in susceptible or high risk individuals such as those already suffering from cardiorespiratory ailments who, when subjected to high levels of air pollution, may suffer increased symptoms or even die.

C-Hypersensitivity phenomena: 1) immunologic and 2) non-specific bronchial hyperreactivity. These are as yet only partially understood. Nevertheless, they should be taken into account by assessing their degree of reversibility and their contribution to health effects.

The better the definition of these types of effects the greater the reliability of determined threshold which will be different for typce C (and possibly different for type A and B) and may also be different for those reactions which are reversible and those which are irreversible.

Additional major problems exist in attempting to define the exposure

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of a population to the pollutants which can either be due to variability in the general outdoor or indoor environment. As indicated by studies reported upon in the ORBES Symposium on Energy and Human Health under certain conditions the differences in the indoor environment may be a greater determinant of observed differences between populations, than the outdoor environment.

The major reasons for the complexity of air pollution and other environmental epidemiological assessment were summarized by Anderson in 1967 (2). His reasons which follow are still valid.

"(1) There are two major forms of community air pollution (a) a 'reducing' form which consists largely of soot and sulfur dioxide and is characterized by London (U.K.) smog, and (b) an "oxidizing" form which consists of carbon monoxide, hydrocarbons, and photochemical decomposition products and is characterized by Los Angeles, California, smog. Although they share a common name, these are two different types of air pollution and it would be misleading to assume that they have the same effect on health.

"(2) Meteorologic variables affect the interpretation of air pollution data and the validity of monitoring, and can increase the duration of exposure to pollutants by preventing their natural dispersion.

"(3) There is a lack of consensus about which pollutants in the air damage health and, which, therefore, need to be monitored.

"(4) The areas of a city in which high levels of air pollution occur usually contain the industries in which the residents work. It is, therefore, hard to assess the health effects of air pollution alone since there will be many other influences on the health of a working population.

"(5) Areas of high air pollution also tend to be areas with blight, poor housing, overcrowding and other deprivation and places in which people of lower social class live.

"(6) When people become ill with respiratory disease they may move from areas of high air pollution. This makes it dangerous to impute a relationship between air pollution and health without also investigating the patterns of and reasons for migration (in some circumstances, for example, it may be the healthier and wealthier who move away).

"(7) The effect of personal air pollution in the form of cigarette smoking is considerably stronger than that of community air pollution in the development of lung cancer and chronic respiratory disease. The importance of the indoor environment in exposure to air pollution must also be considered, and this is discussed in more detail in the section on studies in children."

Thus, the public health effects of the coal and nuclear fuel cycles are numerous and more often than not causation is difficult to disentangle from the influence of other factors such as cigarette smoking, indoor pollution, occupational exposure, etc. Additional problems are associated with the difficulty of assigning damage functions to specific disease states which may be due to air pollution. A review of the literature reveals that the majority of studies attempting to evaluate the health damage due to air pollution use mortality as the damage measure, leaving a great question as to its role in morbidity. Those studies attempting to evaluate morbidity related to air pollution have been few and mostly open to question.

The definitive test of a causal relationship between air pollution and mortality (and between specific components, i.e., sulfur compounds, particulates or some other pollutant) is the demonstration, on a long term basis, of a reduction or increase in mortality as a result of a reduction or increase of air pollution. Such evaluations are currently underway but we cannot afford to wait for the results. Therefore, we chose what we believe to be the most viable path. Namely, to utilize mortality and a range of damage functions based upon the accumulated information available.

The studies, research and the "Symposium on Energy and Human Health: Human Cost of Electric Power Generation" have provided ample evidence of the inherent difficulties involved in developing sound criteria for evaluating current health damage functions, to say nothing about prognosticating the future. It is because of such variations in our state of knowledge that in the following sections we have been forced to present sometimes rather differing conclusions. In addition, in some of the cases the scientific and professional juries have as yet to present their verdict. This situation leaves the planner in a rather precarious position. In fact it is quite conceivable that one set of recommendations based upon inconclusive evidence, no matter how good the intentions, may result in greater damage than the anticipated good.

On the other hand, there is no doubt when we contend with the accidental injuries and deaths in coal mining. In this case or segment of the fossil fuel energy cycle the evidence is clear. Well enforced safety legislation reduces injury and death. In the nuclear fuel cycle, mining again provides a good example of the irrefutable need for reducing exposure to radiation by improved ventilation in uranium mines.

Finally, this document although meant to stand by itself should be

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studied together with two additional ORBES documents: The proceedings of the "Symposium on Energy and Human Health: Human Costs of Electric Power Generation" edited by Dr. Edward P. Radford and Prof. Maurice A. Shapiro (1) and "Impacts on Human Health From the Coal and Nuclear Fuel Cycles and Other Technologies Associated with Electric Power Generation and Transmission" by Edward P. Radford, M.D., Professor Environmental Epidemiology, GSPH, University of Pittsburgh (3).

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Scenarios

A major foundation of the ORBES impact assessment is the series of scenarios or energy-environmental futures. These are more fully detailed in the ORBES Main Report. However, for the sake of completeness of this document we are including in this document abbreviated descriptions of the scenarios.

Business As Usual (Scenario 2)

A variety of alternative plausible futures, or scenarios, were developed for the Ohio River Basin Energy Study. The scenarios are derived from an array of policy assumptions about various conditions in the study region from the base period (the mid-1970s) through the year 2000. These policy assumptions, plus data on current conditions and the use of various scenario models, are the basis for construction of the scenarios themselves. Each scenario analyzed in the project is characterized in terms of basic policy assumptions, exogenous variables (such as the growth in the demand for electricity), energy and fuel use, siting patterns for electrical generating units, sources of coal supply, and underlying dominant social values.

The same annual regional population growth is assumed for all scenarios, including the BAU case. There would be a 15 percent rise in population over the period 1970 to 2000, resulting in an increase from the 1970 ORBES-region population of 23.1 million to a population of 26.6 million in the year 2000. The rise is attributed to in-migration to the region because of power plant construction. For all scenarios, a fertility rate of 2.1 lifetime births per woman is assumed; this is the population replacement rate.

The assumptions underlying the BAU scenario tend to be relatively conventional in terms of the ORBES study region: the use of coal is emphasized, historic patterns of economic growth are followed, and BAU environmental regulations prevail.

Most of the assumed BAU environmental standards are defined in terms of what currently exists as applied to present and future sources of pollution. For air, controls are defined as the application of current (as of September 1978) state implementation plans (SIPs) in urban areas and current rural SIPs in rural areas under the Clean Air Act (42 U.S.C. 1857). New source performance standards (NSPS) are applied to all new sources of pollution. For water, BAU consists of the existing guidelines for the design, construction, and wasteload management of industrial facilities. The BAU controls for land are derived from federal standards prior to the 1977 Surface Mining Control and Reclamation Act. State standards may exceed federal ones. With regard to environmental protection of all receptors, then, this scenario reflects "current" conditions.

More Stringent Environmental Regulations (Scenario 1)

An investigation was made of the policy implications for the ORBES region of relatively strict environmental regulations in conjunction with a push to coal and high rates of economic growth in the ORBES Region and the United States, as in the business as usual case (scenario 2). The only difference between the two scenarios concerns environmental regulations. Under the strict environmental regulations case (scenario 1), the underlying dominant value is health and safety.

In the case of air, strict regulations means that the generally stringent pollutant emission standards for urban areas set by current (as of September 1978) SIPs would be applied throughout a state. For water, guidelines were developed under strict controls that would reduce effluents by about 95 percent from BAU conditions. Strict environmental controls on land call for interim and permanent performance standards under the Surface Mining Control and Reclamation Act of 1977, but with strengthening of site-specific applications; state standards may exceed federal ones. Special interim and permanent standards are applied to steep-slope mining, mountaintop removal, the mining of prime farmland, and the surface effects of underground mining.

The energy and fuel use characteristics remain the same as under the BAU case; as under BAU, total regional installed capacity in the year 2000 would be 153,245 megawatts electric. Assumptions about population growth also remain the same. The strict environmental control assumptions lead to a more dispersed siting pattern for post-1985 electrical generating unit additions from that of the base case. Capacity additions along the middle and lower Ohio River main stem are concentrated on the reach from Cincinnati, Ohio, to Louisville, Kentucky, and in southwestern Indiana and southeastern Illinois in counties bordering the Wabash River. Elsewhere they are located on smaller tributaries away from the Ohio main stem. Fifteen reservoirs are required to accommodate the dispersed siting pattern.

The general pattern of coal supply in the strict control case in the same as that in the BAU case. However, the stricter environmental standards imply reduced efficiency in the transformation of coal to electricity, and, as a consequence, a somewhat higher level of coal demand for production of the same anticipated output to supply the demand for electricity.

Less Stringent Environmental Regulations (Scenario 2d)

The major difference between this case (scenario 2d) and the business as usual case (scenario 2) is with respect to air quality standards, which are defined as noncompliance with state implementation plans (SIPs). However, BAU environmental regulations prevail for water and air.

Export of Electricity from Coal-fired Units (Scenario 2a)

Recently there has been discussion of the possibility of exporting, or "wheeling," power to the middle Atlantic states from coal-fired generating capacity in the ORBES region. In this section, scenario 2a examines the energy and fuel use characteristics of such a policy. Because no previous relevant estimates had been made concerning the magnitude of a potential substitution of regional coal-fired capacity, an estimate was made for purposes of ORBES. Anticipated requirements for the generation of electricity to supply demand within the region are the same as in the BAU case; except for coal and electricity, all fuel and energy levels remain the same. Regional coal use would increase by 103.6 percent between 1974 and 2000; the demand for electricity (including the electricity to be exported from the region) would increase by 126.8 percent.

Low and Very High Economic Growth (Scenario 5 and 5a)

Two scenarios were developed to identify changes in impacts attributable to assumed lower and very high rates of regional economic growth in comparison to the economic growth rates projected under business as usual conditions (scenario 2). In the low economic growth rate scenario (scenario 5), efficiency is a particularly important underlying social value. Whereas the other variations of the BAU case discussed thus far can be distinguished by their alternative policy assumptions, this one can be distinguished in terms of a different value for an exogenous variable, the economic growth rate. In the low economic growth case, the annual regional economic growth rate is 2.1 percent, compared with 2.47 percent in the BAU case. In both cases, the annual national economic growth rate is 3.26 percent.

The change to a low economic growth rate produces fairly dramatic alterations in energy and fuel use from those of BAU. For example, between 1974 and 2000 under the BAU case, coal use increases by 85.2 percent; under the low economic growth case, it increases by 69.6 percent. The demand for electricity increases by 123 percent in the BAU case and by 107.2 percent in the low economic growth case. In the year 2000 under conditions of low economic growth, installed electrical generating capacity in the ORBES region would total 142,195 megawatts electric, 11,050 megawatts less than under BAU conditions. In general, then, the reduction in the regional average annual compounded growth rate produces substantial reductions in anticipated regional fuel and energy use in the year 2000.

The very high regional economic growth scenario (scenario 5a) serves as an extreme upper bound on impacts related to economic growth in the region. Because the very high economic growth case differs from both the BAU case and the low economic growth case only with respect to the rate of economic growth assumed in the ORBES region, three-way comparisons are possible. That is, the very high economic growth case can be compared not only with the BAU case (scenario 2), but also with the low economic growth case (scenario 5). Under the very high economic growth case, an annual regional economic growth rate of 3.1 percent is assumed, compared with 2.47 percent in the BAU case and 2.1 percent in the low economic growth case.

Very Low Energy Growth (Scenario 6)

In this scenario (scenario 6), the specified regional energy and fuel use characteristics reflect a conservation orientation. The overall effects of conservation are assumed to result in a lower rate of regional energy growth than in the business as usual case (scenario 2). This growth rate is 1.9 percent annually through 1985 and 017 percent annually from 1986 through 2000. However, overall economic growth rates are at BAU levels. The question being asked is what differences there are between conservation and nonconservation sets of conditions relating to energy and fuel use characteristics, assuming BAU regional and national economic growth rates. The conservation assumption is introduced through alterations in the energy and fuel demand model, changes in end-use efficiency, lower rates of per capita demand for personal motor power, the mix of energy and fuels for both process and space heat, and industrial and commercial use of air conditioning. These changes can be thought of as changes in lifestyle, produced perhaps by higher relative energy prices or by a conservation ethic, as well as by changes associated with moving along "learning curves." Thus, the values underlying this scenario are conservation/preservation and efficiency.

The effects on energy and fuel use are fairly dramatic. Total demand under low energy growth is only 70 percent of the final demand under BAU conditions.

Higher Electrical Energy Growth (Scenario 7b, 7 and 7a)

Three scenarios were developed to explore the effects of higher rates of growth in the demand for electricity in the ORBES region than the historic growth rate of the business as usual case (scenario 2). The focus again is on coal-fired generating capacity. The primary interest here is the air quality impacts associated with a higher electrical energy growth rate. However, unlike the very high economic growth case in these scenarios only the demand for electricity grows at a high rate; all other energy and fuel uses are assumed to have the same growth rates as they do under BAU conditions. Thus, the ORBES energy and fuel demand model was not run for the high electrical energy growth scenarios. Rather, the high rate in electricity demand growth is treated independently simply by increasing the 1974 demand level at the prescribed rate through the year 2000.

In a variation of high regional electrical energy growth (scenario 7), a 45-year lifetime is assumed for generating units in the ORBES region, rather than the 35-year lifetime assumed for all the scenarios discussed thus far. The 45-lifetime assumption is applied to all units in the region except those whose retirement dates have been scheduled by the utilities. Because of the assumed later requirement of existing units, fewer new electrical generating units would come on-line through the year 2000 than when a 35-year lifetime is assumed under conditions of high electrical energy growth (scenario 7b). Thus, fewer scenario additions are required. Additional units over those of the business as usual case (scenario 2), which also assumes a 35-year lifetime, are sited off the Ohio River main stem, on its major tributaries.

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2. Anderson, I.: "The Effects of Air Contamination on Health"; Canadian Med. Assoc. J., V. 97, 2 Sept. 1967, pp. 528-536.

3. Radford, Edward P.: "Impacts of Human Health from the Coal and Nuclear Fuel Cycles and Other Technologies Associated with Electric Power Generation and Transmission"; Report prepared for ORBES, Subcontract under Prime Contract R805588, University of Pittsburgh, Pittsburgh, PA, July 1980.

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2. GENERAL HEALTH DESCRIPTORS

2.1 PATTERNS OF MORTALITY

The current status of the ORBES region population is characterized in order to establish a perspective and frame of reference. This will hopefully enable us to discern spatial differences in the health status of ORBES residents.

The oldest and perhaps the most reliable measure of a population's health status is the age-adjusted death rate. Mortality data are deemed reliable because virtually every death in the United States is officially registered by year. Examining specific patterns over time for the nation and the six ORBES states (Table 2.1.-1 and Figure 2.1.-1), we see that such rates have reached record lows in the base year 1975 (1). Age adjusted death rates declined dramatically during the first half of the century. By comparison, however, decreases during the period examined in Figure 2.1.-1 (1950-1975) have occurred much more slowly. The greatest group-specific mortality rate decreases during this period have been realized by minority people particularly females. By the mid-fifties rates for minority females equaled those for white males and have been lower since that time (2).

Geographic differences in age-adjusted mortality are, therefore, partly a function of the racial composition of a popoulation and partly a function of the population density. In 1970 the age-adjusted death rate for black males was 33% higher than that for white males. Morevoer, the age-adjusted death rate for black females during the same year was 45% higher than the age-adjusted death rate for white females (1). Consequently, areas with a high proportion of negroes tend to exhibit higher death rates than areas inhabited by caucasians.

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As can be seen in Figure 2.1.-1, during the twenty-five years prior to the base year each of the six ORBES states (with the exception of Ohio in the early fifties) have exhibited age-adjusted death rates greater than the national rate. From 1950 until 1962 the highest ORBES state-specific, age-adjusted mortality rates occurred in the Commonwealth of Pennsylvania. Since approximately 1962 the state of West Virginia has had the highest age-adjusted mortality rate of the six ORBES states.

Two major difficulties complicate the task of characterizing the health status of ORBES residents: 1) the fact that "health status" is somewhat of a nebulous concept to begin with, and 2) the fact that the 423 counties within the ORBES Region make for an unwieldy amount of data to interpret, regardless of the measure(s) chosen to illustrate health status. In order to simplify this matter and facilitate identification of health "hot spots" we have selected five indicators of health status: age-adjusted death rates for all causes, infant mortality for all causes, age-adjusted respiratory (lung, trachea, and bronchus) cancer mortality for white females, identical cancer mortality for white males, and percent of total deaths due to ischemic heart disease.

Each of these measures have been acquired at the county level. Crude mortality rates for 1970 (3) were age-adjusted by using the 1960 U.S. population as the standard. Infant mortality was obtained as a five year arithmetic average for the period 1969-1973. Respiratory cancer mortality rates for white males and white females were obtained from the U.S. Department of Health, Education and Welfare's "U.S. Cancer Mortality by County: 1950-1969 (4)." These cancer rates are also age-adjusted using the 1960 U.S. population as a standard. Percent of deaths due to ischemic heart disease is an average for the period 1970-1974, inclusive (3).

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The 10% of the counties in the ORBES Region with the highest and the lowest mortality rates in each of the five health indicators are shown in Figures 2.1.-2 through 2.1.-6 and are listed by state in Tables 2.1.-2 through 2.1.-11.

The tables also give the z-score of each county listed. Z-scores are the difference between an observation and the mean of all observations, for a particular health measure, divided by the standard deviation of the observations:

$$z_i = \frac{x_i - \bar{x}}{\sigma}$$

6-1/2"
9-1/8"

Thus, the higher the z-score the higher is the mortality rate of a county. Also, a positive z-score indicates higher than average mortality while a negative z-score indicates a lower than average mortality rate.

The z-scores can be conveniently used to derive a "health status index" by calculating the arithmetic average of the z-scores obtained for a county in several health indicators (5). These average z-scores were calculated from the z-scores of the five mortality rates for each of the 423 counties in the ORBES Region and the negative of these averages will be used here to rank the counties according to the overall health of their populace.

Figure 2.1.-7 shows and Tables 2.1.-12 and 2.1.-13 list the 10% of the counties in the ORBES Region with the highest and the lowest health status index values. Table 2.1.-14 lists the z-scores of all ORBES Region Counties, the health status index, and ranking by the health status index within each state and within the entire ORBES Region.

An implicit assumption in the use of the health status index is that the health measures used in the calculation of the index are normally

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distributed. Analysis of the distribution of the five mortality rates selected herein revealed this to be the case.

Of the six ORBES states, Kentucky and West Virginia display the highest concentration of counties with high age-adjusted mortality rates, high infant mortality rates, and high female respiratory cancer mortality rates. However, Kentucky also exhibits a high concentration of counties with low male respiratory rates and low ischemic heart disease mortality rates. As a result, when individual death rate statistics were used to calculate a health status index for each ORBES county, Kentucky was the state with the greatest percentage of counties with high (healthy) status index values. West Virignia, on the other hand, was the state with the greatest percentage of counties with a low (unhealthy) index. Of the four remaining ORBES states, Illinois displayed a very high concentration of counties with high ischemic heart disease mortality rates.

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4. Mason, T.J. and F. W. McKay: "U.S. Cancer Mortality by County: 1950-1969;" DHEW Publ. No. (NIH) 74-615, Bethesda, MD, 1974.
5. Donabedian, M.: "Research and Development of a Relative Community Health Index;" Paper Presented Before the Scientific and Technical Advisors Conference, June 6, 1973. U.S. Dept. Commerce, NTIS, HRP-0016041, Springfield, VA, 1973.

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FIGURE 2.1.-1

AGE-ADJUSTED DEATH RATES
OF THE
SIX ORBES STATES AND THE NATION

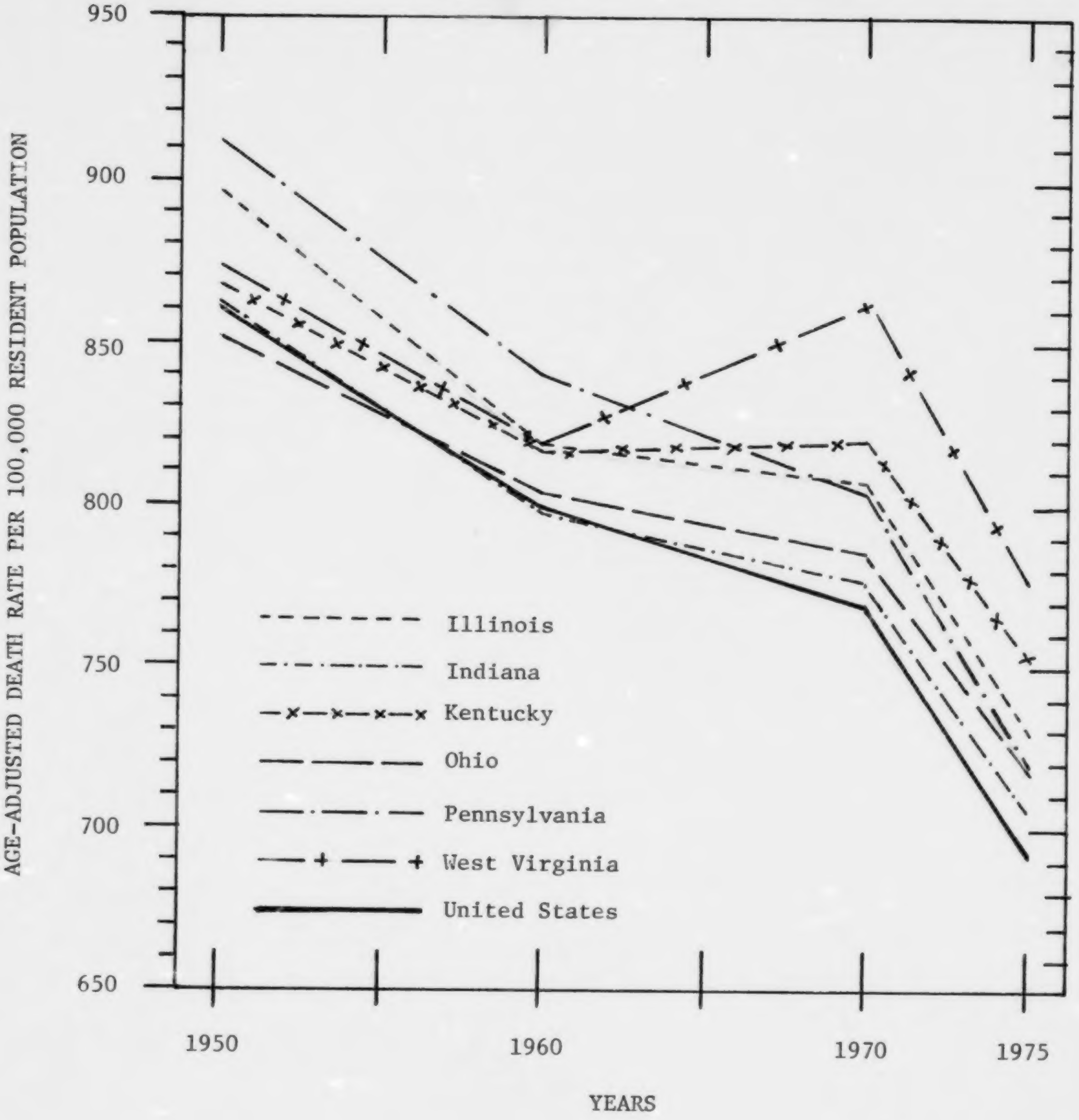


FIGURE 2.1.-2

ORBES COUNTIES WITH THE HIGHEST AND LOWEST AGE-ADJUSTED MORTALITY RATES FROM ALL CAUSES IN 1970

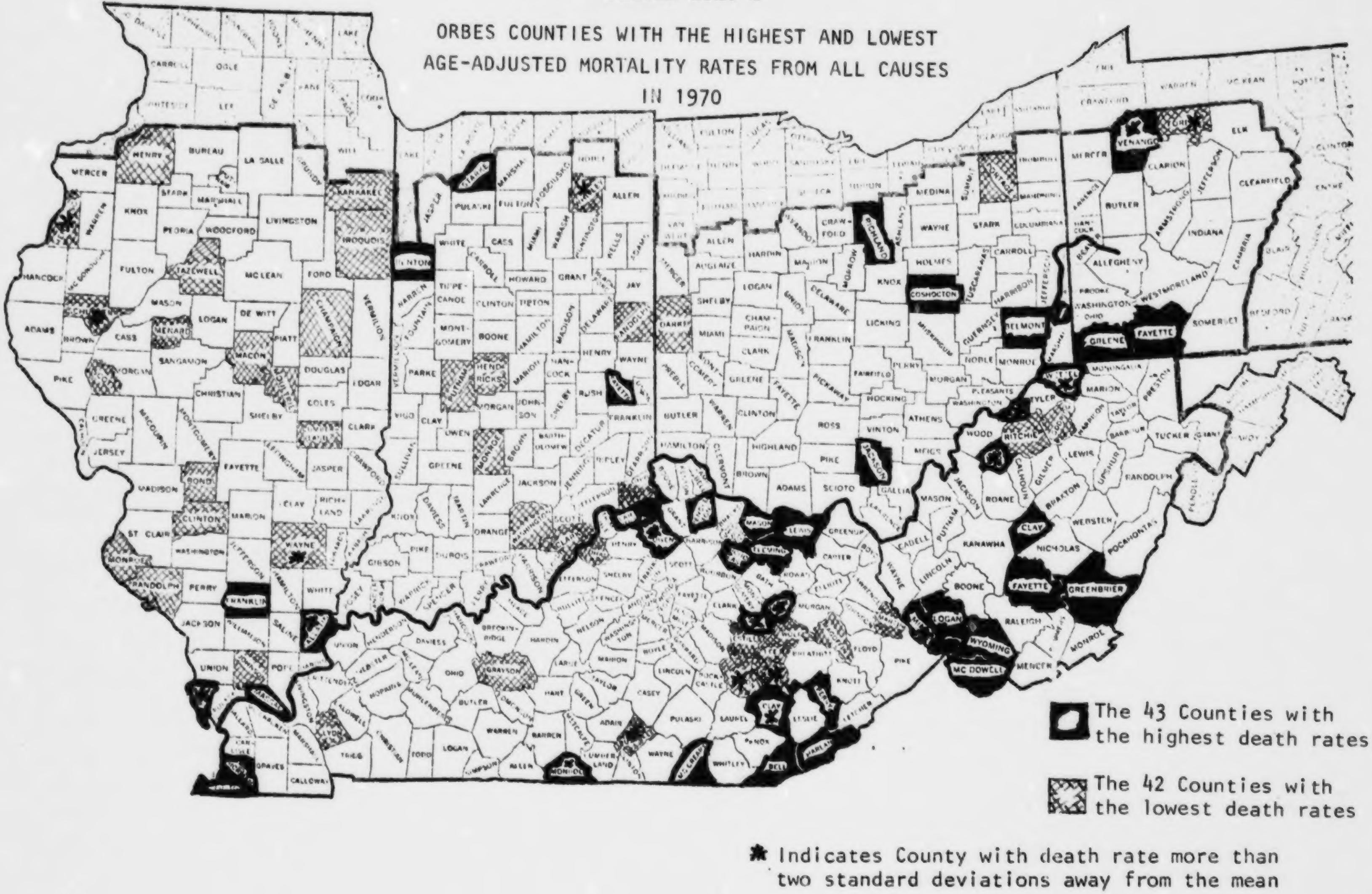
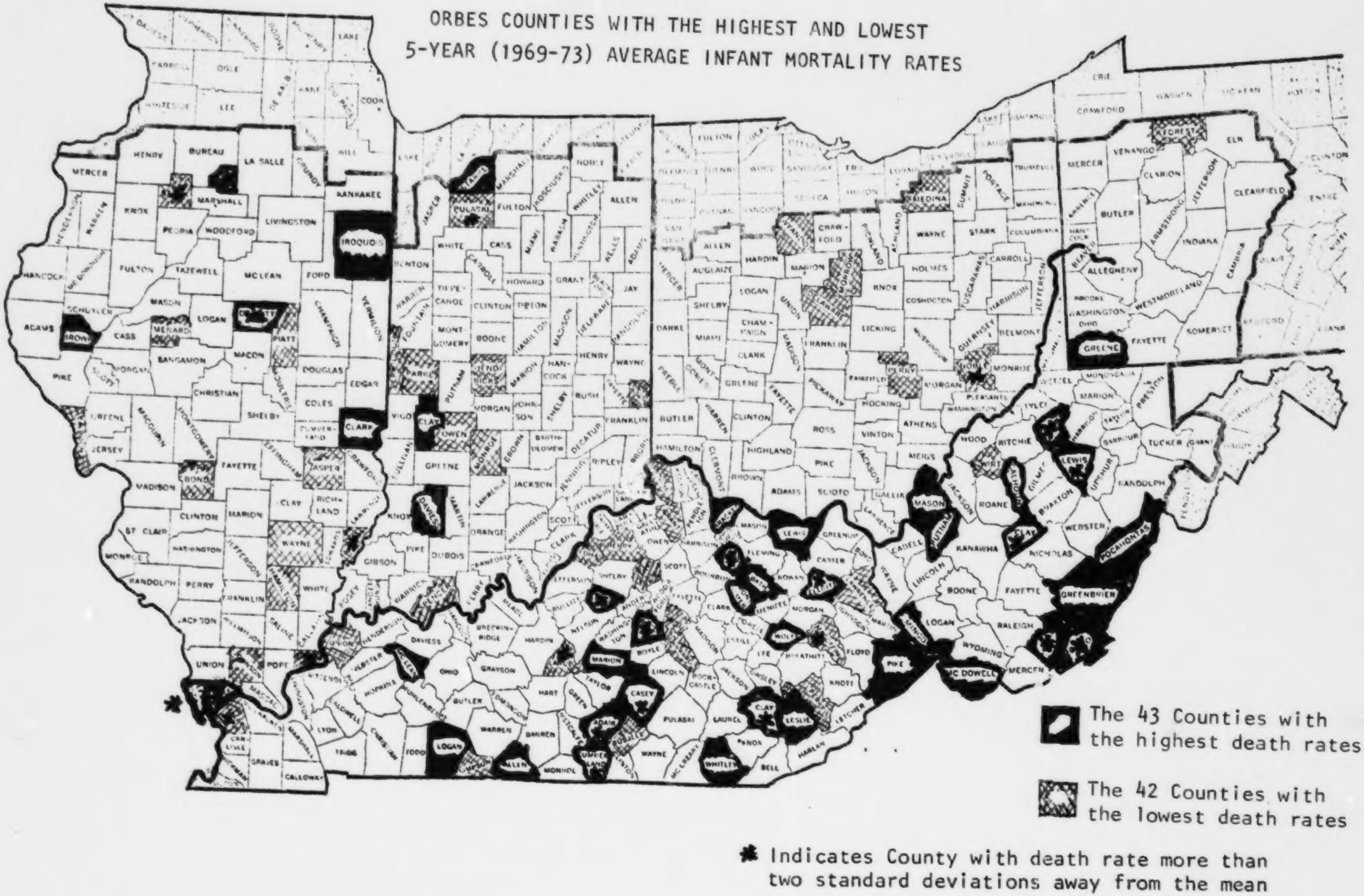

The 43 Counties with the highest death rates
The 42 Counties with the lowest death rates
* Indicates County with death rate more than two standard deviations away from the mean

FIGURE 2.1.-3

ORBES COUNTIES WITH THE HIGHEST AND LOWEST
5-YEAR (1969-73) AVERAGE INFANT MORTALITY RATES



OGLE
LEE
COOK
HENRY
BUREAU
LA SALLE
GRUNDY
KANKAKEE
MERCER
KNOX
MARSHALL
PEORIA
WOODFORD
LIVINGSTON
IROQUOIS
FULTON
TAZEWELL
MC LEAN
FORD
HANCOCK
SCHUYLER
ADAMS
BROWN
CASS
MASON
MENARD
LOGAN
PIATT
CHAMPAIGN
VERMILION
PIKE
SANGAMON
MACON
DOUGLAS
EDGAR
CHRISTIAN
SHELBY
COLES
CLARK
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MARION
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SUMMIT
PORTAGE
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STARK
MERCER
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MORROW
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MADISON
FRANKLIN
LICKING
GUERNSEY
NOBLE
MONROE
PREBLE
MONTGOMERY
GREENE
FAYETTE
PICKAWAY
FAIRFIELD
PERRY
MORGAN
BUTLER
WARREN
CLINTON
ROSS
HOCKING
ATHENS
VINTON
WASHINGTON
HAMILTON
CLERMONT
HIGHLAND
PIKE
JACKSON
MEIGS
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
ERIE
CRAWFORD
WARREN
MC KEAN
MERCER
VENANGO
FOREST
ELK
CLARION
JEFFERSON
CLEARFIELD
BUTLER
ARMSTRONG
INDIANA
CAMBRIA
BEAVER
ALLEGHENY
WESTMORELAND
WASHINGTON
SOMERSET
BEDFORD
GREENE
FAYETTE
WETZEL
MONONGALIA
MARION
PRESTON
TYLER
TUCKER
GRANT
PLEASANTS
WOOD
RITCHIE
LEWIS
UPSHUR
RANDOLPH
WIRT
CALHOUN
GILMER
BRAXTON
MASON
JACKSON
ROANE
PUTNAM
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CLAY
WEBSTER
POCAHONTAS
NICHOLAS
CABELL
WAYNE
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FAYETTE
GREENBRIER
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WYOMING
MC DOWELL
MERCER
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LEWIS
GREENUP
FLEMING
CARTER
ROWAN
BATH
MENIFEE
MORGAN
ELLIOTT
WOLFE
BREATHITT
FLOYD
KNOTT
LEE
ESTILL
POWELL
CLARK
SCOTT
OWEN
SHELBY
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ROCKCASTLE
JACKSON
TAYLOR
CASEY
GREEN
HART
ADAIR
PULASKI
LAUREL
CLAY
LESLIE
LETCHER
KNOX
HARLAN
BELL
WHITLEY
MC CREARY
WAYNE
CUMBERLAND
METCALFE
BARREN
WARREN
LOGAN
TODD
ALLEN
MONROE
BUTLER
HOPKINS
CHRISTIAN
CALDWELL

The 43 Counties with the highest death rates

The 42 Counties with the lowest death rates

* Indicates County with death rate more than two standard deviations away from the mean

FIGURE 2.1.-4

ORBES COUNTIES WITH THE HIGHEST AND LOWEST 20-YEAR (1950-69) AVERAGE, AGE-ADJUSTED, WHITE, FEMALE RESPIRATORY CANCER MORTALITY RATES

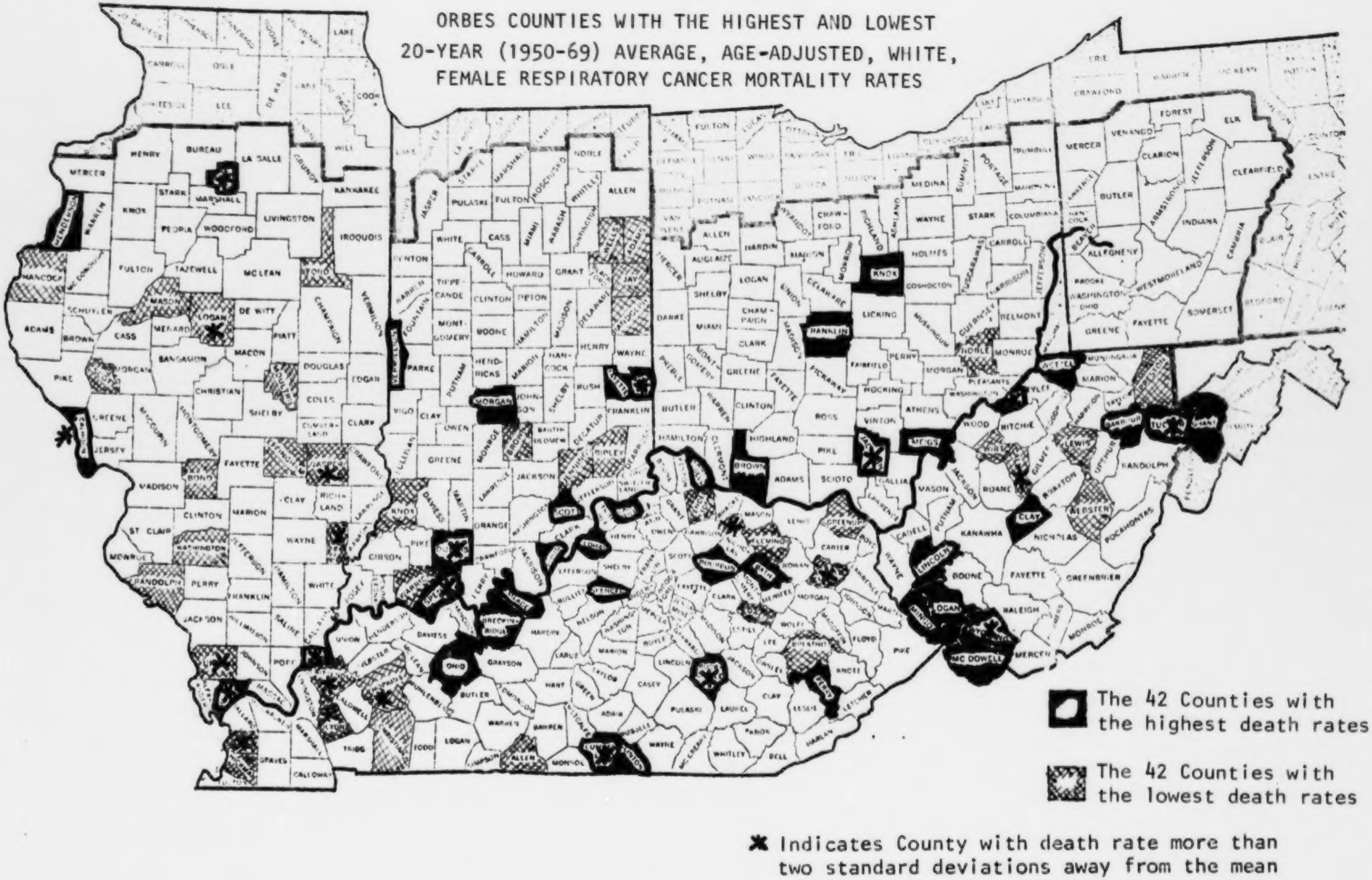
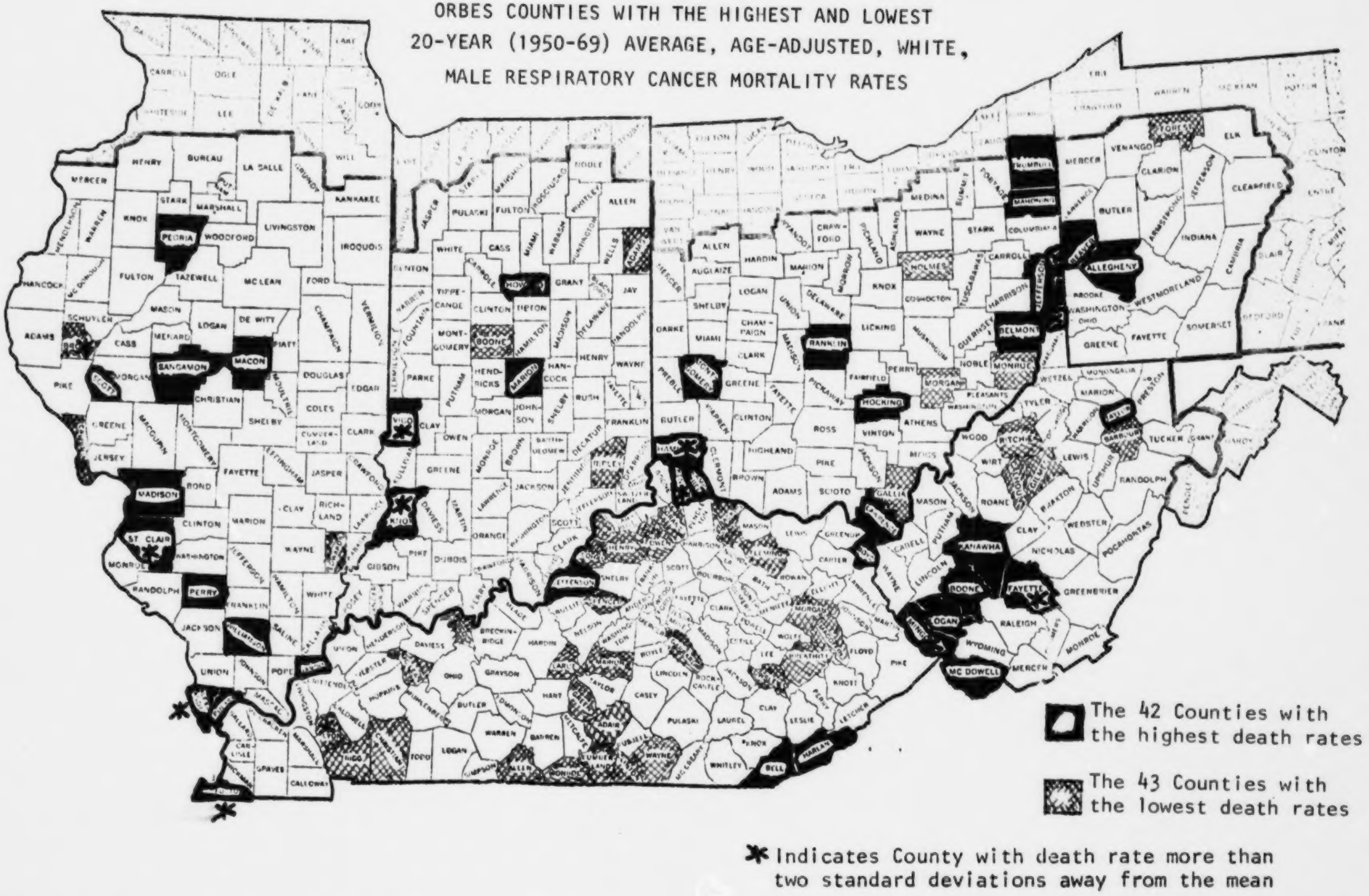

■ The 42 Counties with the highest death rates
▨ The 42 Counties with the lowest death rates
✱ Indicates County with death rate more than two standard deviations away from the mean

FIGURE 2.1.-5

ORBES COUNTIES WITH THE HIGHEST AND LOWEST 20-YEAR (1950-69) AVERAGE, AGE-ADJUSTED, WHITE, MALE RESPIRATORY CANCER MORTALITY RATES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KNOX
HOWARD
BOONE
MARION
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HAMILTON
FRANKLIN
HOCKING
HOLMES
MORGAN
MONROE
BELMONT
JEFFERSON
TRUMBULL
MAHONING
BEAVER
ALLEGHENY
FOREST
GALLIA
LAWRENCE
KANAWHA
BOONE
FAYETTE
LOGAN
MINGO
MC DOWELL
RITCHIE
BARBOUR
BELL
HARLAN
HENRY
MERCER
KNOX
STARK
MARSHALL
WOODFORD
LIVINGSTON
LA SALLE
BUREAU
FULTON
TAZEWELL
MC LEAN
FORD
IROQUOIS
KANKAKEE
CHAMPAIGN
VERMILION
DOUGLAS
EDGAR
COLES
CLARK
JASPER
WAYNE
CLINTON
WASHINGTON
JEFFERSON
HAMILTON
FRANKLIN
JACKSON
UNION
POPE
ADAMS
PIKE
GREENE
JERSEY
CHRISTIAN
SHELBY
FAYETTE
BOND
ALLEN
ADAMS
JAY
WELLS
GRANT
CASS
WHITE
PULASKI
FULTON
TIPPE-CANOE
CLINTON
TIPTON
PARKE
PUTNAM
CLAY
OWEN
GREENE
DAVIESS
GIBSON
PIKE
DUBOIS
ORANGE
JACKSON
BROWN
HENRY
RUSH
DECATUR
HAN-COCK
HEND-RICKS
JOHN-SON
SHELBY
BUTLER
CLERMONT
PREBLE
DARKE
MIAMI
GREENE
CLINTON
HIGHLAND
BROWN
ADAMS
SCIOTO
PIKE
ROSS
VINTON
ATHENS
MEIGS
JACKSON
PICKAWAY
LICKING
KNOX
WAYNE
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HARRISON
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MUSKINGUM
NOBLE
GUERNSEY
TUSCARAWAS
COLUMBIANA
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BARREN
LOGAN
TODD
HART
CASEY
PULASKI
LAUREL
CLAY
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WHITLEY
LINCOLN
BOYLE
FLOYD
KNOTT
PIKE
PERRY
LETCHER
CALLOWAY
GRAVES
CARLISLE
UNION
ADAIR
TAYLOR
WAYNE

▇ The 42 Counties with the highest death rates

▨ The 43 Counties with the lowest death rates

* Indicates County with death rate more than two standard deviations away from the mean

FIGURE 2.1.-6

ORBES COUNTIES WITH THE HIGHEST AND LOWEST
5-YEAR (1970-74) AVERAGE OF PERCENT MORTALITY
DUE TO ISCHEMIC HEART DISEASE

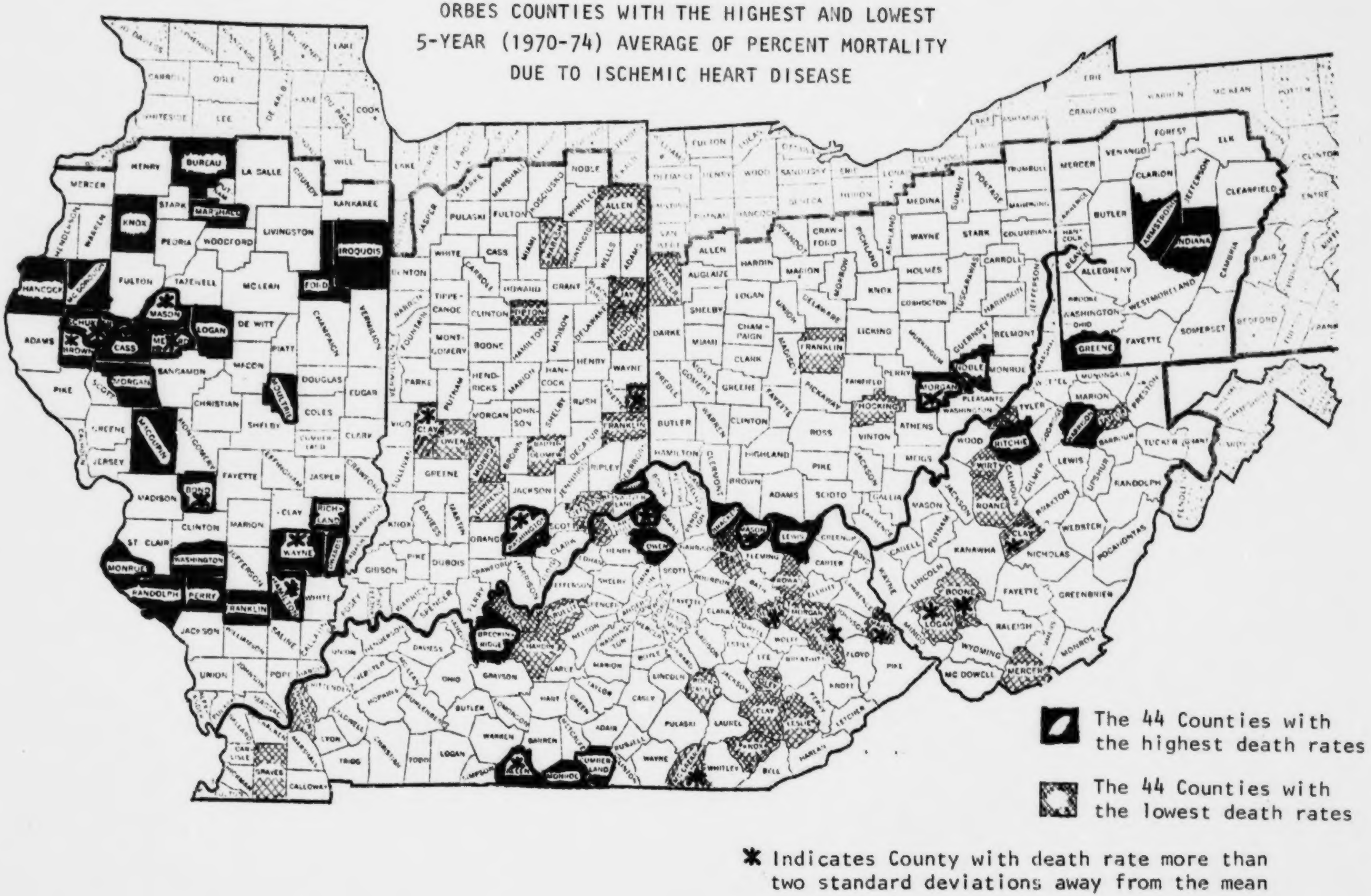
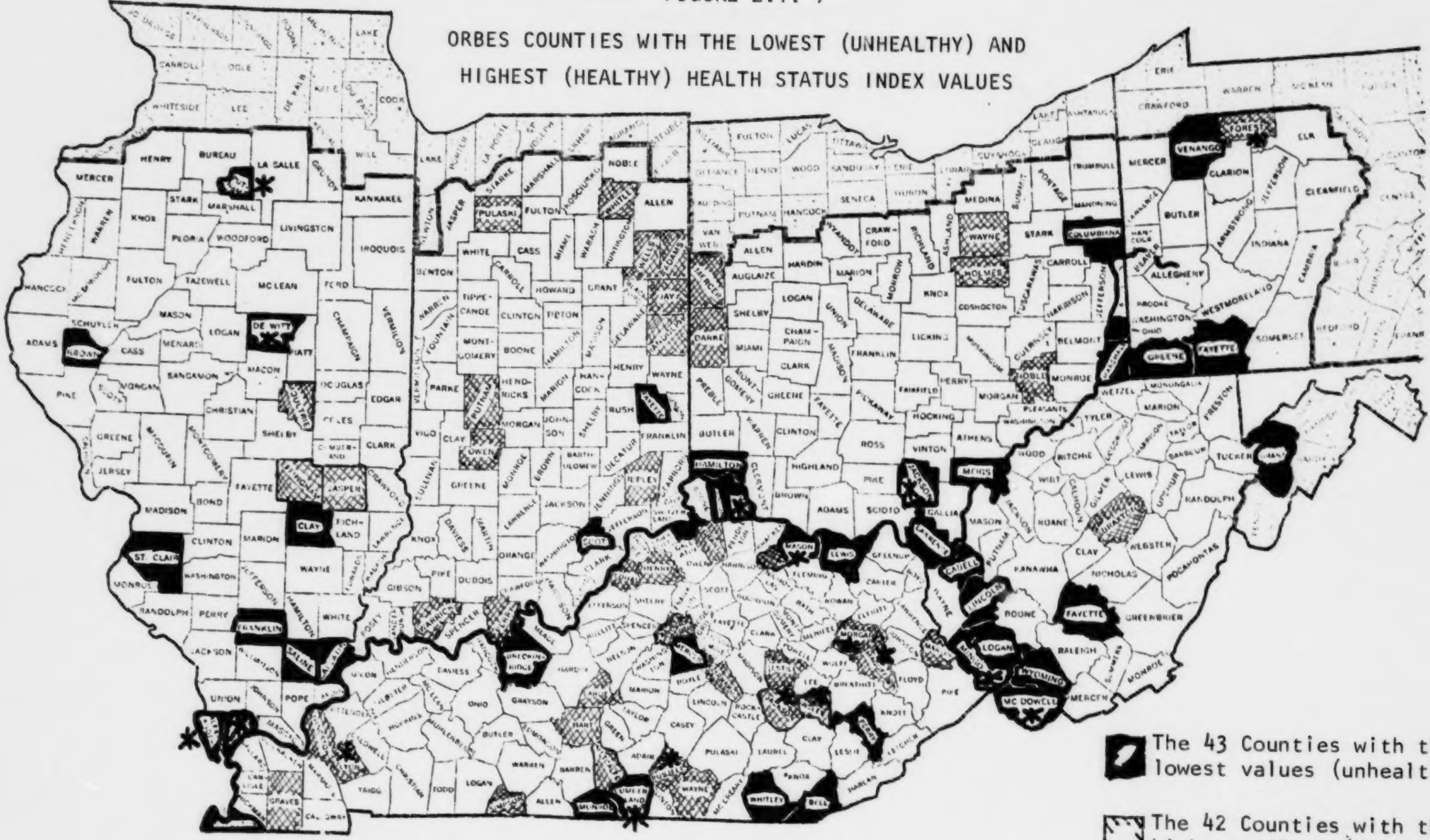

■ The 44 Counties with the highest death rates
▨ The 44 Counties with the lowest death rates
* Indicates County with death rate more than two standard deviations away from the mean

FIGURE 2.1.-7

ORBES COUNTIES WITH THE LOWEST (UNHEALTHY) AND HIGHEST (HEALTHY) HEALTH STATUS INDEX VALUES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KANKAKEE
IROQUOIS
FULTON
TAZEWELL
McLEAN
FORD
HANCOCK
SCHUYLER
MASON
LOGAN
DE WITT
CHAMPAIGN
VERMILION
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CASS
MENARD
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MACOUPIN
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CLAY
RICHLAND
ST. CLAIR
CLINTON
MARION
WAYNE
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HAMILTON
WHITE
JACKSON
SALINE
UNION
POPE
CARROLL
OGLE
WHITESIDE
LEE
DE KALB
COOK
LAKE
WILL
GRUNDY
JASPER
STARKE
PULASKI
FULTON
MARSHALL
NOBLE
ALLEN
WHITLEY
WHITE
CASS
MIAMI
WABASH
BENTON
CARROLL
HOWARD
GRANT
TIPPECANOE
CLINTON
TIPTON
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MONTGOMERY
BOONE
HAMILTON
MADISON
DELAWARE
DARKE
HENDRICKS
HANCOCK
HENRY
WAYNE
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RUSH
FAYETTE
VIGO
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MORGAN
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FRANKLIN
OWEN
GREENE
MONROE
BROWN
BARTHOLOMEW
DECATUR
RIPLEY
JACKSON
SULLIVAN
KNOX
DAVIESS
MARTIN
ORANGE
GIBSON
PIKE
DUBOIS
SPENCER
SCOTT
CLARK
FULTON
LUCAS
HENRY
WOOD
SANDUSKY
ERIE
LORAIN
CUYAHOGA
PUTNAM
HANCOCK
SENECA
HURON
MEDINA
SUMMIT
PORTAGE
TRUMBULL
VAN WERT
ALLEN
HARDIN
WYANDOT
CRAWFORD
RICHLAND
ASHLAND
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MAHONING
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DODDRIDGE
HARRISON
TAYLOR
BARBOUR
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GRANT
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SUMMERS
MONROE
MINGO
WYOMING
McDOWELL
MERCER
MASON
LEWIS
GREENUP
CARTER
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SCOTT
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LYON
CRITTENDEN
LIVINGSTON
MARSHALL
GRAVES
CALLOWAY
CARLISLE
HICKMAN
NELSON
WASHINGTON
MARION
SPENCER
BULLITT
JEFFERSON
OLDHAM
TRIMBLE
CARROLL
GALLATIN
BOONE
GRANT
PENDLETON
BRACKEN
HARRISON
BOURBON
NICHOLAS
FAYETTE
JESSAMINE
GARRARD
ANDERSON
WOODFORD
FRANKLIN

■ The 43 Counties with the lowest values (unhealthy)

▨ The 42 Counties with the highest values (healthy)

✱ Indicates County with index value more than one standard deviation away from the mean

TABLE 2.1.-1

AGE-ADJUSTED DEATH RATES
OF THE
SIX ORBES STATES AND THE NATION

(death/100,000 resident population)

State	Year			
	1950	1960	1970	1975
Illinois	895.8	818.9	807.3	731.2
Indiana	861.7	796.6	775.9	705.6
Kentucky	873.5	815.5	820.4	753.1
Ohio	851.9	802.8	785.3	717.8
Pennsylvania	911.9	839.6	803.2	720.1
West Virginia	867.5	819.1	861.9	777.2
United States	860.7	797.8	769.3	692.9

SOURCE: U.S. Department of Health, Education, and Welfare (1).

TABLE 2.1.-2

THE 43 COUNTIES WITH THE HIGHEST AGE-ADJUSTED MORTALITY FROM ALL CAUSES IN 1970 IN THE ORBES REGION
(z-scores in parentheses)

ILLINOIS		OHIO	
Alexander	(2.33)	Belmont	(1.18)
Franklin	(1.37)	Coshocton	(1.20)
Gallatin	(3.08)	Highland	(1.46)
Massac	(1.94)	Jackson	(1.37)
INDIANA		PENNSYLVANIA	
Benton	(1.24)	Fayette	(1.18)
Fayette	(1.48)	Greene	(1.50)
Starke	(1.69)	Venango	(2.38)
KENTUCKY		WEST VIRGINIA	
Bell	(1.70)	Clay	(1.99)
Carroll	(1.90)	Fayette	(1.47)
Clay	(2.61)	Greenbrier	(1.33)
Fleming	(1.37)	Logan	(1.84)
Fulton	(1.48)	McDowell	(1.94)
Gallatin	(1.39)	Mingo	(2.96)
Harlan	(1.80)	Ohio	(1.36)
Hickman	(3.18)	Pleasants	(2.94)
Lewis	(1.32)	Wetzel	(2.24)
Mason	(1.44)	Wirt	(3.13)
McCreary	(1.31)	Wyoming	(1.49)
Menifee	(2.97)		
Monroe	(2.02)		
Nicholas	(1.87)		
Owen	(2.32)		
Pendleton	(1.36)		
Perry	(1.40)		
Powell	(2.30)		

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TABLE 2.1.-3

THE 42 COUNTIES WITH THE LOWEST AGE-ADJUSTED MORTALITY RATES FROM ALL CAUSES IN 1970 IN THE ORBES REGION.
(z-scores in parentheses)

ILLINOIS

Bond	(-1.81)
Champaign	(-1.23)
Clinton	(-1.45)
Cumberland	(-1.28)
Henderson	(-2.22)
Henry	(-1.48)
Iroquois	(-1.73)
Johnson	(-1.30)
Kankakaee	(-1.42)
Macon	(-1.58)
Menard	(-1.81)
Monroe	(-1.19)
Moultrie	(-1.72)
Randolph	(-1.43)
Schuyler	(-3.15)
Scott	(-1.77)
Tazewell	(-1.69)
Wayne	(-2.55)

INDIANA

Clark	(-1.19)
Hendricks	(-1.11)
Monroe	(-1.40)
Putnam	(-1.77)
Randolph	(-1.10)
Switzerland	(-1.65)
Washington	(-1.30)
Whitley	(-2.13)

KENTUCKY

Estill	(-1.47)
Grayson	(-1.76)
Jackson	(-4.29)
Lee	(-1.39)
Lyon	(-1.42)
Magoffin	(-1.73)
Martin	(-1.47)
Oldham	(-1.85)
Owsley	(-3.14)
Russell	(-2.05)
Wolfe	(-1.61)

OHIO

Darke	(-1.30)
Portage	(-1.57)

PENNSYLVANIA

Forest	(-2.75)

WEST VIRGINIA

Doddridge	(-1.66)
Ritchie	(-1.24)

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TABLE 2.1.-4

THE 43 COUNTIES WITH THE HIGHEST 5-YEAR (1969-73) AVERAGE INFANT MORTALITY RATES IN THE ORBES REGION

(z-scores in parentheses)

Illinois		Kentucky		Pennsylvania	
Alexander	(3.10)	Adair	(2.91)	Greene	(1.22)
Brown	(1.79)	Allen	(1.75)	**West Virginia**	
Clark	(1.43)	Bath	(1.24)	Calhoun	(1.41)
DeWitt	(3.03)	Bracken	(1.41)	Clay	(2.04)
Iroquois	(1.26)	Casey	(2.15)	Doddridge	(3.73)
Pulaski	(2.70)	Clay	(2.13)	Greenbrier	(1.69)
Putnam	(2.95)	Cumberland	(3.48)	Lewis	(2.80)
Indiana		Elliott	(3.24)	Mason	(1.88)
Clay	(1.43)	Leslie	(1.96)	McDowell	(1.24)
Daviess	(1.64)	Lewis	(1.37)	Mingo	(1.64)
Starke	(1.37)	Logan	(1.26)	Monroe	(2.55)
		Marion	(1.92)	Pochahontas	(1.98)
		McLean	(1.45)	Putnam	(1.60)
		Mercer	(2.57)	Summers	(2.40)
		Montgomery	(1.60)		
		Nicholas	(3.63)		
		Pike	(1.16)		
		Spencer	(2.87)		
		Whitley	(1.62)		
		Woolfe	(1.47)		

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TABLE 2.1.-5

THE 42 COUNTIES WITH THE LOWEST 5-YEAR (1969-73) AVERAGE INFANT MORTALITY RATES IN THE ORBES REGION
(z-scores in parentheses)

Illinois	
Bond	(-1.06)
Calhoun	(-1.27)
Hamilton	(-1.73)
Hardin	(-3.65)
Jasper	(-1.29)
Johnson	(-1.14)
Menard	(-1.12)
Piatt	(-1.24)
Stark	(-2.49)
Wabash	(-2.55)
Wayne	(-1.81)

Indiana	
Hendricks	(-1.39)
Monroe	(-1.41)
Owen	(-1.41)
Parke	(-1.62)
Pulaski	(-2.34)
Spencer	(-1.29)
Union	(-1.54)
Vermillion	(-1.75)

Kentucky	
Anderson	(-1.96)
Ballard	(-2.05)
Boone	(-1.25)
Garrard	(-1.14)
Grant	(-1.58)
Henry	(-1.48)
Jessamine	(-1.10)
Larue	(-2.38)
Lawrence	(-1.56)
Magoffin	(-2.09)
Oldham	(-1.60)
Perry	(-1.06)
Russell	(-1.18)
Simpson	(-1.50)
Union	(-1.06)

Ohio	
Delaware	(-1.20)
Medina	(-1.20)
Morrow	(-1.35)
Noble	(-2.21)
Perry	(-1.31)
Wyandott	(-1.14)

Pennsylvania	
Forest	(-1.94)

West Virginia	
Wirt	(-1.48)

TABLE 2.1.-6

THE 42 COUNTIES WITH THE HIGHEST 20-YEAR (1950-69) AVERAGE, AGE-ADJUSTED, WHITE, FEMALE RESPIRATORY CANCER MORTALITY RATES IN THE ORBES REGION

(z-scores in parentheses)

Illinois		Kentucky		Ohio	
Calhoun	(2.39)	Bath	(1.28)	Brown	(1.23)
Hardin	(2.39)	Bourbon	(1.34)	Franklin	(1.28)
Henderson	(1.62)	Breckinridge	(1.23)	Jackson	(2.00)
Pulaski	(3.72)	Campbell	(1.89)	Knox	(1.34)
Putnam	(2.78)	Carroll	(1.56)	Meigs	(1.23)
		Clinton	(1.23)		
Indiana		Cumberland	(2.45)	**West Virginia**	
		Meade	(1.67)		
Dubois	(2.00)	Ohio	(1.39)	Barbour	(1.50)
Fayette	(1.34)	Oldham	(1.34)	Clay	(1.34)
Floyd	(1.45)	Perry	(1.45)	Grant	(1.89)
Morgan	(1.73)	Rockcastle	(2.06)	Lincoln	(1.62)
Scott	(1.78)	Spencer	(1.34)	Logan	(1.95)
Spencer	(2.00)			McDowell	(1.39)
Union	(2.28)			Mingo	(1.67)
Vermillion	(1.84)			Pleasants	(2.23)
				Tucker	(2.11)
				Wetzel	(1.34)
				Wyoming	(2.56)

TABLE 2.1.-7

THE 42 COUNTIES WITH THE LOWEST 20-YEAR (1950-69) AVERAGE, AGE-ADJUSTED, WHITE, FEMALE RESPIRATORY CANCER MORTALITY RATES IN THE ORBES REGION
(z-scores in parentheses)

Illinois	
Bond	(-1.88)
Edwards	(-2.60)
Effingham	(-1.65)
Ford	(-1.65)
Hancock	(-1.82)
Jasper	(-2.43)
Logan	(-2.04)
Mason	(-1.60)
Moultrie	(-1.38)
Randolph	(-1.32)
Scott	(-1.60)
Union	(-2.10)
Washington	(-1.49)

Indiana	
Adams	(-1.60)
Brown	(-1.77)
Jay	(-1.71)
Jennings	(-1.54)
Knox	(-1.38)
Randolph	(-1.38)
Ripley	(-1.77)
Warrick	(-1.43)
Wells	(-1.43)

Kentucky	
Allen	(-1.77)
Breathitt	(-1.93)
Carlisle	(-2.54)
Christian	(-1.43)
Crittenden	(-2.21)
Elliott	(-2.54)
Fleming	(-1.65)
Greenup	(-1.65)
Hickman	(-1.38)
Hopkins	(-2.10)
Lyon	(-2.54)
Pendleton	(-1.65)
Powell	(-1.54)
Robertson	(-2.54)

Ohio	
Noble	(-1.32)

West Virginia	
Calhoun	(-2.49)
Lewis	(-1.49)
Preston	(-1.88)
Webster	(-1.32)
Wirt	(-1.49)

TABLE 2.1.-8

THE 42 COUNTIES WITH THE HIGHEST 20-YEAR (1950-69) AVERAGE, AGE-ADJUSTED, WHITE, MALE RESPIRATORY CANCER MORTALITY RATES IN THE ORBES REGION

(z-scores in parentheses)

Illinois	
Alexander	(2.26)
Hardin	(1.50)
Macon	(1.46)
Madison	(1.57)
Peoria	(1.40)
Perry	(1.75)
Pulaski	(1.71)
St. Clair	(2.47)
Sangamon	(1.67)
Scott	(1.61)
Williamson	(1.53)

Indiana	
Howard	(2.21)
Knox	(2.49)
Marion	(1.84)
Vigo	(2.29)

Kentucky	
Bell	(1.53)
Boyd	(1.61)
Campbell	(1.90)
Fulton	(2.84)
Harlan	(1.29)
Jefferson	(1.77)
Kenton	(2.46)

Ohio	
Belmont	(1.39)
Franklin	(1.76)
Hamilton	(2.17)
Hocking	(1.46)
Jefferson	(1.43)
Lawrence	(1.44)
Mahoning	(1.52)
Montgomery	(1.38)
Trumbull	(1.34)

Pennsylvania	
Allegheny	(1.70)
Beaver	(1.51)

West Virginia	
Boone	(1.52)
Brooke	(1.88)
Fayette	(2.47)
Hancock	(3.03)
Kanawha	(1.91)
Logan	(1.61)
McDowell	(1.56)
Mingo	(2.00)
Ohio	(2.46)
Taylor	(1.43)

TABLE 2.1.-9

THE 43 COUNTIES WITH THE LOWEST 20-YEAR (1950-69) AVERAGE, AGE-ADJUSTED, WHITE, MALE RESPIRATORY CANCER MORTALITY RATES IN THE ORBES REGION

(z-scores in parentheses)

State	County	z-score
Illinois	Brown	(-2.37)
	Calhoun	(-1.42)
	Edwards	(-1.26)
Indiana	Adams	(-1.48)
	Boone	(-1.23)
	Ripley	(-1.62)
Kentucky	Adair	(-1.72)
	Allen	(-1.43)
	Bracken	(-1.49)
	Breathitt	(-1.27)
	Christian	(-1.64)
	Clinton	(-1.61)
	Cumberland	(-1.48)
	Fleming	(-1.54)
	Garrard	(-1.31)
	Grant	(-1.25)
	Green	(-1.49)
	Hancock	(-1.64)
	Henry	(-1.36)
	Larue	(-1.66)
	Lyon	(-2.77)
	McLean	(-1.80)
	Magoffin	(-1.77)
	Marion	(-1.32)
	Monroe	(-1.37)
	Morgan	(-1.78)
	Oldham	(-1.31)
	Owen	(-1.74)
	Owsley	(-1.65)
	Robertson	(-1.25)
	Spencer	(-1.77)
	Trigg	(-1.74)
	Trimble	(-1.68)
	Wayne	(-1.94)
Ohio	Gallia	(-1.37)
	Holmes	(-1.77)
	Monroe	(-1.88)
	Morgan	(-1.29)
Pennsylvania	Forest	(-1.89)
West Virginia	Barbour	(-1.62)
	Calhoun	(-1.78)
	Gilmer	(-1.43)
	Ritchie	(-1.27)

TABLE 2.1.-10

THE 44 COUNTIES WITH THE HIGHEST 5-YEAR (1970-74) AVERAGE OF PERCENT MORTALITY DUE TO ISCHEMIC HEART DISEASE IN THE ORBES REGION
(z-scores in parentheses)

Illinois	
Bond	(2.18)
Brown	(2.60)
Bureau	(1.33)
Cass	(1.54)
Edwards	(1.75)
Ford	(1.54)
Franklin	(1.97)
Hamilton	(2.18)
Hancock	(1.33)
Iroquois	(1.33)
Knox	(1.33)
Logan	(1.33)
McDonough	(1.33)
Macoupin	(1.33)
Marshall	(1.54)
Mason	(2.39)
Menard	(2.60)
Monroe	(1.75)
Morgan	(1.75)
Moultrie	(1.33)
Perry	(1.97)
Randolph	(1.33)
Richland	(1.54)
Schuyler	(5.15)
Washington	(1.75)
Wayne	(2.18)

Indiana	
Ohio	(1.33)
Washington	(2.18)

Kentucky	
Allen	(3.24)
Bracken	(1.97)
Breckinridge	(1.54)
Cumberland	(1.33)
Gallatin	(2.18)
Lewis	(1.33)
Mason	(2.60)
Monroe	(1.97)
Owen	(1.33)

Ohio	
Morgan	(2.60)
Noble	(1.33)

Pennsylvania	
Armstrong	(1.33)
Greene	(1.97)
Indiana	(1.75)

West Virginia	
Harrison	(1.33)
Ritchie	(1.33)

TABLE 2.1.-11

THE 44 COUNTIES WITH THE LOWEST 5-YEAR (1970-74) AVERAGE OF PERCENT MORTALITY DUE TO ISCHEMIC HEART DISEASE IN THE ORBES REGION

(z-scores in parentheses)

Indiana	
Allen	(-1.22)
Bartholomew	(-1.22)
Clay	(-2.07)
Franklin	(-1.22)
Jay	(-1.86)
Jefferson	(-1.43)
Lawrence	(-1.65)
Monroe	(-1.43)
Owen	(-1.86)
Randolph	(-1.65)
Tipton	(-1.43)
Union	(-2.07)
Wabash	(-1.22)

Kentucky	
Bullitt	(-1.43)
Clay	(-1.65)
Graves	(-1.86)
Hardin	(-1.65)
Knox	(-1.22)
Leslie	(-1.43)
Livingston	(-1.22)
McCreary	(-2.50)
Magoffin	(-2.28)
Martin	(-2.50)
Meade	(-1.86)
Menifee	(-2.07)
Montgomery	(-1.22)
Morgan	(-1.86)
Nicholas	(-1.43)
Owsley	(-1.65)
Robertson	(-1.43)
Rockcastle	(-1.22)
Rowan	(-1.22)
Trimble	(-1.22)

Ohio	
Franklin	(-1.86)
Hocking	(-1.65)
Mercer	(-1.22)

West Virginia	
Boone	(-2.28)
Clay	(-3.35)
Logan	(-2.07)
Mercer	(-1.43)
Pleasants	(-1.22)
Roane	(-1.65)
Taylor	(-1.43)
Wirt	(-1.65)

TABLE 2.1.-12

THE 43 COUNTIES WITH THE LOWEST (UNHEALTHY) HEALTH STATUS INDEX VALUES IN THE ORBES REGION

(negative mean of five mortality indicator z-scores in parentheses)

State	County	Value
Illinois	Alexander	(-1.79)
	Brown	(-0.69)
	Clay	(-0.70)
	DeWitt	(-1.03)
	Franklin	(-0.86)
	Gallatin	(-0.82)
	Pulaski	(-1.79)
	Putnam	(-1.23)
	St. Clair	(-0.94)
	Saline	(-0.68)
Indiana	Fayette	(-0.76)
	Scott	(-0.66)
Kentucky	Bell	(-0.73)
	Breckinridge	(-0.62)
	Campbell	(-1.07)
	Cumberland	(-1.21)
	Fulton	(-0.73)
	Gallatin	(-0.65)
	Kenton	(-0.86)
	Lewis	(-0.72)
	Mason	(-1.02)
	Mercer	(-0.94)
	Monroe	(-0.63)
	Perry	(-0.76)
	Whitley	(-0.72)
Ohio	Columbiana	(-0.63)
	Hamilton	(-0.63)
	Jackson	(-1.08)
	Lawrence	(-0.71)
	Meigs	(-0.69)
Pennsylvania	Fayette	(-0.63)
	Greene	(-0.87)
	Venango	(-0.71)
West Virginia	Cabell	(-0.74)
	Fayette	(-0.69)
	Grant	(-0.67)
	Lincoln	(-0.64)
	Logan	(-0.77)
	McDowell	(-1.07)
	Marshall	(-0.62)
	Mingo	(-1.62)
	Ohio	(-0.92)
	Wyoming	(-0.91)

TABLE 2.1.-13

THE 42 COUNTIES WITH THE HIGHEST (HEALTHY) HEALTH STATUS INDEX VALUES IN THE ORBES REGION

(negative mean of five mortality indicator z-scores in parentheses)

Illinois		**Kentucky**		**Ohio**	
Effingham	(0.87)	Anderson	(0.84)	Darke	(0.57)
Jasper	(0.77)	Estill	(0.58)	Holmes	(0.61)
Moultrie	(0.57)	Garrard	(0.60)	Mercer	(0.89)
Indiana		Grant	(0.70)	Noble	(0.64)
Adams	(0.72)	Graves	(0.62)	Wayne	(0.74)
Jay	(0.73)	Hart	(0.79)	**Pennsylvania**	
Owen	(0.83)	Henry	(0.66)	Forest	(1.02)
Perry	(0.63)	Jackson	(1.17)	**West Virginia**	
Pulaski	(0.54)	Larue	(0.97)	Braxton	(0.64)
Putnam	(0.72)	Livingston	(0.62)		
Randolph	(0.91)	Lyon	(1.23)		
Ripley	(0.76)	Magoffin	(1.49)		
Warrick	(0.54)	Martin	(0.71)		
Wells	(0.56)	Metcalfe	(0.54)		
Whitley	(0.93)	Morgan	(1.27)		
		Oldham	(0.84)		
		Owsley	(1.38)		
		Robertson	(0.91)		
		Russell	(1.02)		
		Simpson	(0.58)		
		Wayne	(0.79)		

TABLE 2.1.-14 SUMMARY OF ORBES COUNTY HEALTH STATUS EVALUATION DATA

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
ILLINOIS									
ADAMS	17001	0.37	0.74	-0.93	0.51	0.69	-0.28	108	25
ALEXANDER	17003	2.33	2.26	0.56	3.10	0.69	-1.79	1	1
BOND	17005	-1.81	0.14	-1.88	-1.06	2.18	0.49	369	81
BROWN	17009	1.06	-2.37	0.34	1.79	2.60	-0.69	30	9
BUREAU	17011	-0.68	0.27	-0.49	-0.04	1.33	-0.08	170	40
CALHOUN	17013	-0.29	-1.42	2.39	-1.27	-0.16	0.15	262	57
CASS	17017	0.28	0.65	-1.10	-0.53	1.54	-0.17	135	30
CHAMPAIGN	17019	-1.23	-0.13	-0.27	-0.21	-0.58	0.48	367	79
CHRISTIAN	17021	0.50	1.09	-1.05	-1.01	0.27	0.04	214	49
CLARK	17023	0.56	-0.35	-0.77	1.43	-0.16	-0.14	144	31
CLAY	17025	0.56	0.62	0.34	0.88	1.12	-0.70	29	8
CLINTON	17027	-1.45	-0.02	0.06	-0.57	0.48	0.30	316	70
COLES	17029	-0.12	0.97	-0.38	0.72	0.27	-0.29	105	24
CRAWFORD	17033	-0.29	0.79	1.06	-0.15	0.27	-0.33	97	20
CUMBERLAND	17035	-1.28	0.18	-1.27	-0.38	0.27	0.50	373	82
DE WITT	17039	-0.32	1.11	0.45	3.03	0.90	-1.03	9	4
DOUGLAS	17041	0.41	-0.65	0.23	-0.40	0.69	-0.06	177	42
EDGAR	17045	-0.52	0.24	-0.71	0.31	0.69	-0.00	194	45
EDWARDS	17047	0.22	-1.26	-2.60	-0.04	1.75	0.38	343	75
EFFINGHAM	17049	-0.73	-0.02	-1.65	-0.93	-1.01	0.87	413	85
FAYETTE	17051	0.03	-0.89	1.17	0.04	0.27	-0.12	155	36
FORD	17053	-0.02	0.08	-1.65	0.02	1.54	0.01	197	46
FRANKLIN	17055	1.37	0.98	0.12	-0.15	1.97	-0.86	16	6
FULTON	17057	-0.19	-0.47	0.29	0.51	0.27	-0.08	171	41
GALLATIN	17059	3.08	0.28	0.12	0.13	0.48	-0.82	18	7
GREENE	17061	-0.20	0.74	-0.93	0.27	0.05	0.01	198	47
GRUNDY	17063	0.39	-0.36	0.51	-0.08	0.05	-0.10	161	38
HAMILTON	17065	-0.59	0.27	-1.27	-1.73	2.18	0.23	292	63
HANCOCK	17067	-0.81	-0.03	-1.82	-0.04	1.33	0.27	308	68
HARDIN	17069	0.85	1.50	2.39	-3.65	-0.58	-0.10	162	39
HENDERSON	17071	-2.22	-0.32	1.62	-0.99	0.69	0.24	297	65
HENRY	17073	-1.48	-0.21	0.17	0.04	0.69	0.16	267	59
IROQUOIS	17075	-1.73	-0.47	-0.55	1.26	1.33	0.03	207	48
JACKSON	17077	0.55	0.97	0.67	-0.09	0.69	-0.56	51	12
JASPER	17079	-0.87	-0.38	-2.43	-1.29	1.12	0.77	406	84
JEFFERSON	17081	-0.35	0.41	0.62	-0.72	-1.22	0.25	299	66
JERSEY	17083	-0.20	0.68	0.01	-0.87	-0.16	0.11	247	54
JOHNSON	17087	-1.30	-0.25	0.67	-1.14	0.27	0.35	331	73
KANKAKEE	17091	-1.42	-0.24	-0.55	0.86	0.69	0.13	257	56
KNOX	17095	-0.58	0.41	0.56	0.59	1.33	-0.46	68	15
LA SALLE	17099	0.11	0.21	-0.16	0.21	0.27	-0.13	150	33
LAWRENCE	17101	-0.53	0.10	-0.66	0.78	0.48	-0.04	185	43
LIVINGSTON	17105	-1.02	-0.30	-0.71	0.23	0.27	0.31	318	72
LOGAN	17107	-1.04	0.29	-2.04	-0.28	1.33	0.35	332	74
MC DONOUGH	17109	-1.05	-0.06	-0.77	-0.97	1.33	0.30	317	71
MC LEAN	17113	-0.63	0.11	-0.93	0.00	0.90	0.11	248	55
MACON	17115	-1.58	1.46	0.17	0.19	-0.58	0.07	227	52
MACOUPIN	17117	0.41	0.59	-0.60	-1.01	1.33	-0.14	145	32
MADISON	17119	-0.70	1.57	0.40	-0.19	0.27	-0.27	111	27
MARION	17121	-0.12	0.75	0.84	0.13	0.48	-0.42	77	16
MARSHALL	17123	-0.59	-0.67	-1.21	-1.01	1.54	0.39	346	76
MASON	17125	-0.94	0.30	-1.60	-0.51	2.39	0.07	228	53
MASSAC	17127	1.94	0.82	0.07	-0.02	-0.80	-0.53	56	13
MENARD	17129	-1.81	-0.61	0.17	-1.12	2.60	0.15	263	58
MERCER	17131	-0.09	-0.27	-0.21	-0.36	1.12	-0.03	188	44
MONROE	17133	-1.19	-0.23	-0.77	1.10	1.75	-0.13	151	34
MONTGOMERY	17135	0.15	0.17	0.01	-0.34	1.12	-0.22	126	29

TABLE 2.1.-14 Continued

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
MORGAN	17137	-0.50	-0.21	-0.27	0.78	1.75	-0.31	102	22
MOULTRIE	17139	-1.72	-0.79	-1.38	-0.30	1.33	0.57	387	83
PEORIA	17143	-0.74	1.40	0.51	0.34	-0.16	-0.27	112	28
PERRY	17145	-0.58	1.75	-0.66	-0.46	1.97	-0.41	83	19
PIATT	17147	-0.04	-0.15	-0.16	-1.24	0.48	0.22	286	61
PIKE	17149	-0.04	0.70	0.67	0.53	0.69	-0.51	59	14
POPE	17151	-0.46	0.43	-0.66	0.74	0.48	-0.11	159	37
PULASKI	17153	0.74	1.71	3.72	2.70	0.05	-1.79	2	2
PUTNAM	17155	1.05	0.57	2.78	2.95	-1.22	-1.23	4	3
RANDOLPH	17157	-1.43	0.27	-1.32	-1.14	1.33	0.46	365	78
RICHLAND	17159	-0.91	0.62	-0.44	0.67	1.54	-0.30	103	23
ST. CLAIR	17163	0.53	2.47	0.56	1.07	0.05	-0.94	11	5
SALINE	17165	0.49	1.20	0.40	0.40	0.90	-0.68	33	10
SANGAMON	17167	-0.15	1.67	0.78	0.08	0.48	-0.57	49	11
SCHUYLER	17169	-3.15	-0.12	0.12	-0.59	5.15	-0.28	109	26
SCOTT	17171	-1.77	1.61	-1.60	0.59	0.90	0.05	219	51
SHELBY	17173	-0.83	-0.32	0.06	-0.21	0.05	0.25	300	67
STARK	17175	-0.00	-0.56	-0.21	-2.49	1.12	0.43	357	77
TAZEWELL	17179	-1.69	1.11	-0.21	-0.21	-0.37	0.27	309	69
UNION	17181	0.87	-0.05	-2.10	-0.36	0.48	0.23	293	64
VERMILION	17183	0.28	1.28	0.56	0.34	-0.37	-0.42	78	17
WABASH	17185	0.34	-0.07	0.17	-2.55	1.12	0.20	280	60
WARREN	17187	0.87	-0.61	-0.60	0.50	0.48	-0.13	152	35
WASHINGTON	17189	-0.09	-0.80	-1.49	0.42	1.75	0.04	215	50
WAYNE	17191	-2.55	-0.62	0.40	-1.81	2.18	0.48	368	80
WHITE	17193	0.61	0.24	0.29	0.08	0.90	-0.42	79	18
WILLIAMSON	17199	-0.66	1.53	0.62	-0.74	0.90	-0.33	98	21
WOODFORD	17203	-0.84	-0.65	-0.55	0.27	0.69	0.22	287	62
INDIANA									
ADAMS	18001	-0.74	-1.48	-1.60	0.57	-0.37	0.72	401	77
ALLEN	18003	-0.96	0.58	-0.27	-0.08	-1.22	0.39	347	61
BARTHOLOMEW	18005	-0.27	0.47	0.17	0.46	-1.22	0.08	235	36
BENTON	18007	1.24	-0.15	-0.10	-0.61	-0.16	-0.04	186	25
BLACKFORD	18009	0.62	-0.13	-0.71	-0.15	-0.80	0.23	294	50
BOONE	18011	-0.81	-1.23	-0.16	-0.44	0.48	0.43	358	65
BROWN	18013	-1.05	0.45	-1.77	0.08	-0.16	0.49	370	69
CARROLL	18015	-1.04	-0.24	-0.82	0.23	-0.80	0.53	377	71
CASS	18017	-0.22	0.56	0.06	0.42	0.05	-0.18	132	15
CLARK	18019	-1.19	1.14	0.12	-0.17	-0.37	0.10	244	39
CLAY	18021	-0.07	0.73	-1.21	1.64	-2.07	0.20	281	48
CLINTON	18023	0.53	0.56	0.17	0.17	-0.80	-0.13	153	20
CRAWFORD	18025	-0.39	-0.72	0.62	-0.57	0.90	0.03	208	30
DAVIESS	18027	0.25	0.53	-0.82	1.64	0.05	-0.33	99	10
DEARBORN	18029	-0.22	-0.26	-0.49	0.57	0.05	0.07	229	34
DECATUR	18031	-0.01	-0.39	-0.05	-0.63	-0.16	0.25	301	53
DELAWARE	18035	0.34	0.76	0.17	0.15	-0.58	-0.17	136	16
DUBOIS	18037	-0.20	-0.78	2.00	-0.65	0.05	-0.09	166	22
FAYETTE	18041	1.48	0.39	1.34	0.97	-0.37	-0.76	20	1
FLOYD	18043	-0.24	0.62	1.45	-0.13	-0.37	-0.27	113	12
FOUNTAIN	18045	0.62	0.77	-0.82	-0.17	-1.01	0.12	254	41
FRANKLIN	18047	0.06	-1.09	-0.49	0.10	-1.22	0.53	378	72
FULTON	18049	-0.11	0.43	0.40	-0.91	-0.16	0.07	230	35
GIBSON	18051	-0.32	0.71	-0.05	-0.61	0.27	-0.00	195	28
GRANT	18053	-0.02	0.70	-0.05	-0.30	-0.37	0.01	199	29
GREENE	18055	0.71	-0.11	-0.55	-0.15	-0.80	0.18	274	46
HAMILTON	18057	-0.58	0.33	-0.32	-0.44	-0.37	0.28	312	56
HANCOCK	18059	-0.69	0.00	-0.32	0.46	-0.58	0.23	295	51
HARRISON	18061	0.22	-1.12	-0.66	-0.63	0.05	0.42	355	64

TABLE 2.1.-14 Continued

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
HENDRICKS	18063	-1.11	1.17	0.01	-1.39	-0.37	0.34	326	58
HENRY	18065	-0.90	0.02	-0.44	0.25	-0.16	0.25	302	54
HOWARD	18067	-0.03	2.21	-0.49	0.13	-1.01	-0.16	140	18
HUNTINGTON	18069	0.84	-0.49	-0.49	-0.15	-0.16	0.09	238	37
JACKSON	18071	0.23	0.05	-0.82	-0.13	-0.58	0.25	303	55
JASPER	18073	-0.14	0.49	-0.27	-0.47	0.27	0.03	209	31
JAY	18075	-0.05	-0.11	-1.71	0.08	-1.86	0.73	403	79
JEFFERSON	18077	-1.03	-0.45	0.23	1.01	-1.43	0.34	327	59
JENNINGS	18079	0.37	-0.03	-1.54	0.02	-1.01	0.44	362	66
JOHNSON	18081	0.14	0.97	0.67	-0.76	-0.16	-0.17	137	17
KNOX	18083	0.09	2.49	-1.38	-0.02	-0.80	-0.08	172	23
KOSCIUSKO	18085	-0.22	-0.25	-0.88	-0.89	0.05	0.44	363	67
LAWRENCE	18093	0.15	1.08	0.62	-0.66	-1.65	0.09	239	38
MADISON	18095	-0.53	0.73	-0.44	-0.06	-0.58	0.17	270	44
MARION	18097	-0.05	1.84	1.01	0.17	-0.89	-0.43	76	6
MARSHALL	18099	-1.03	0.09	-0.60	0.12	-0.58	0.40	349	62
MARTIN	18101	1.21	0.20	0.23	-0.30	0.05	-0.28	110	11
MIAMI	18103	-0.09	1.08	-0.55	0.02	-0.58	0.03	210	32
MONROE	18105	-1.40	0.58	1.06	-1.41	-1.43	0.52	375	70
MONTGOMERY	18107	-0.61	-0.18	0.73	-0.30	-0.80	0.23	296	52
MORGAN	18109	-0.73	0.87	1.73	-0.80	-0.58	-0.10	163	21
NOBLE	18113	0.13	0.71	-0.99	0.44	-0.16	-0.03	189	26
OHIO	18115	0.01	-0.79	0.01	1.14	1.33	-0.34	96	9
ORANGE	18117	0.08	-0.99	-0.49	1.10	-0.58	0.18	275	47
OWEN	18119	-0.56	0.32	-0.66	-1.41	-1.86	0.83	410	81
PARKE	18121	1.01	-0.27	-0.44	-1.62	0.27	0.21	283	49
PERRY	18123	-0.26	-0.15	-1.16	-0.78	-0.80	0.63	395	76
PIKE	18125	0.26	0.69	-0.05	0.99	0.48	-0.48	65	5
POSEY	18129	-0.68	0.52	0.01	-0.84	0.27	0.14	258	42
PULASKI	18131	0.17	-0.73	0.78	-2.34	-0.58	0.54	383	73
PUTNAM	18133	-1.77	-0.15	-0.05	-0.84	-0.30	0.72	402	78
RANDOLPH	18135	-1.10	-0.43	-1.38	0.00	-1.65	0.91	415	82
RIPLEY	18137	-1.09	-1.62	-1.77	-0.23	0.90	0.76	405	80
RUSH	18139	0.14	-0.25	0.51	0.27	0.48	-0.23	123	14
SCOTT	18143	0.96	-0.02	1.78	1.14	-0.58	-0.66	35	2
SHELBY	18145	-0.11	1.02	0.56	-0.32	-0.37	-0.16	141	19
SPENCER	18147	-1.09	-1.12	2.00	-1.29	0.05	0.29	313	57
STARKE	18149	1.69	0.15	-0.49	1.37	-0.80	-0.38	87	7
SULLIVAN	18153	1.06	1.26	0.17	-0.30	0.48	-0.53	57	4
SWITZERLAND	18155	-1.65	-0.24	-0.44	0.65	-0.37	0.41	353	63
TIPPECANOE	18157	-0.69	0.88	-0.60	-1.12	-0.80	0.47	366	68
TIPTON	18159	-0.63	0.43	-0.32	0.25	-1.43	0.34	328	60
UNION	18161	0.53	0.67	2.28	-1.54	-2.07	0.03	211	33
VANDERBURGH	18163	-0.84	1.06	0.90	-0.42	-0.37	-0.07	173	24
VERMILLION	18165	0.47	1.33	1.84	-1.75	0.90	-0.56	52	3
VIGO	18167	0.05	2.29	0.45	-0.55	-0.37	-0.37	91	8
WABASH	18169	0.91	0.15	-0.38	-0.32	-1.22	0.17	271	45
WARREN	18171	0.83	0.38	1.01	-0.08	-0.80	-0.27	114	13
WARRICK	18173	-0.32	-0.73	-1.43	-0.25	0.05	0.54	384	74
WASHINGTON	18175	-1.30	-0.97	-0.44	-0.21	2.18	0.15	264	43
WAYNE	18177	-0.81	0.79	-0.60	0.51	-0.37	0.10	245	40
WELLS	18179	-0.33	-0.53	-1.43	-0.80	0.27	0.56	386	75
WHITE	18181	0.04	0.94	-0.32	0.21	-0.80	-0.01	192	27
WHITLEY	18183	-2.13	-0.12	-1.27	-0.11	-1.01	0.93	417	83
KENTUCKY									
ADAIR	21001	0.23	-1.72	-0.38	2.91	-0.80	-0.05	182	42
ALLEN	21003	0.52	-1.43	-1.77	1.75	3.24	-0.46	69	18
ANDERSON	21005	0.22	-0.54	-0.93	-1.96	-1.01	0.84	411	111

TABLE 2.1.-14 Continued

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
BALLARD	21007	-0.12	0.15	0.34	-2.05	1.12	0.11	249	61
BARREN	21009	0.43	-0.83	0.12	-0.04	0.90	-0.12	156	36
BATH	21011	0.86	-1.17	1.28	1.24	-1.01	-0.24	122	29
BELL	21013	1.70	1.53	1.06	0.38	-1.01	-0.73	23	7
BOONE	21015	-0.63	0.33	0.67	-1.25	-0.37	0.25	304	74
BOURBON	21017	-0.23	-0.23	1.34	-0.27	-0.37	-0.05	183	43
BOYD	21019	-0.79	1.61	0.56	-0.51	0.48	-0.27	115	26
BOYLE	21021	0.91	-0.91	-0.55	0.80	-0.58	0.07	231	56
BRACKEN	21023	0.17	-1.49	0.84	1.41	1.97	-0.58	48	15
BREATHITT	21025	0.42	-1.27	-1.93	-0.57	0.90	0.49	371	96
BRECKINRIDGE	21027	0.73	-0.89	1.23	0.51	1.54	-0.62	42	13
BULLITT	21029	-0.26	1.16	-0.44	-0.87	-1.43	0.37	341	85
BUTLER	21031	0.66	-1.14	-0.38	-0.32	-0.58	0.35	333	82
CALDWELL	21033	-0.09	-0.92	-0.10	0.23	0.05	0.17	272	67
CALLOWAY	21035	-0.82	-1.20	0.12	-0.57	-0.16	0.53	379	99
CAMPBELL	21037	1.06	1.90	1.89	-0.21	0.69	-1.07	7	2
CARLISLE	21039	0.51	-0.06	-2.54	0.48	0.69	0.18	276	68
CARROLL	21041	1.90	-1.21	1.56	-0.63	-0.16	-0.29	106	25
CARTER	21043	0.61	-0.88	0.40	-0.78	-0.80	0.29	314	77
CASEY	21045	-1.03	-1.09	-0.82	2.15	0.05	0.15	265	66
CHRISTIAN	21047	0.94	-1.64	-1.43	-0.06	0.05	0.43	359	93
CLARK	21049	-0.56	-0.48	0.56	0.08	1.12	-0.14	146	34
CLAY	21051	2.61	-1.21	1.12	2.13	-1.65	-0.60	45	14
CLINTON	21053	-0.47	-1.61	1.23	0.88	-0.58	0.11	250	62
CRITTENDEN	21055	0.49	-0.61	-2.21	0.97	-0.80	0.43	360	94
CUMBERLAND	21057	0.26	-1.48	2.45	3.48	1.33	-1.21	5	1
DAVIESS	21059	-0.27	-0.18	0.95	0.12	-0.37	-0.05	184	44
EDMONSON	21061	-0.17	-0.95	0.12	-1.03	-0.58	0.52	376	98
ELLIOTT	21063	0.59	-1.03	-2.54	3.24	0.05	-0.06	178	40
ESTILL	21065	-1.47	-1.02	0.67	-0.93	-0.16	0.58	389	101
FAYETTE	21067	0.01	0.40	0.17	-0.65	-0.16	0.04	216	51
FLEMING	21069	1.37	-1.54	-1.65	0.59	0.90	0.07	232	57
FLOYD	21071	1.05	0.43	1.12	0.21	-0.58	-0.44	73	21
FRANKLIN	21073	1.08	0.29	0.06	0.08	-0.37	-0.23	124	30
FULTON	21075	1.48	2.84	-0.88	0.38	-0.16	-0.73	24	8
GALLATIN	21077	1.39	0.47	0.34	-1.14	2.18	-0.65	36	11
GARRARD	21079	0.14	-1.31	-0.93	-0.72	-0.16	0.60	391	103
GRANT	21081	-0.83	-1.25	0.34	-1.58	-0.16	0.70	399	107
GRAVES	21083	-0.32	-0.66	-0.93	0.69	-1.86	0.62	393	104
GRAYSON	21085	-1.76	-1.03	0.67	-0.55	0.90	0.35	334	83
GREEN	21087	0.98	-1.49	0.17	0.23	-1.01	0.22	288	71
GREENUP	21089	-0.55	0.08	-1.65	-0.09	0.27	0.39	348	88
HANCOCK	21091	-0.14	-1.64	1.12	1.09	-0.80	0.07	233	58
HARDIN	21093	-0.18	-0.26	0.06	-0.08	-1.65	0.42	356	92
HARLAN	21095	1.60	1.29	-0.88	0.88	-0.58	-0.50	62	16
HARRISON	21097	0.34	-0.84	0.34	1.01	0.48	-0.26	116	27
HART	21099	-1.01	-1.00	-0.93	-0.21	-0.80	0.79	407	109
HENDERSON	21101	-0.28	0.47	0.34	-0.59	-0.16	0.04	217	52
HENRY	21103	0.85	-1.36	-0.93	-1.48	-0.37	0.66	398	106
HICKMAN	21105	3.18	-0.08	-1.38	0.63	0.05	-0.48	66	17
HOPKINS	21107	-0.34	-0.39	-2.10	0.59	0.27	0.40	350	89
JACKSON	21109	-4.29	-1.02	0.78	-0.55	-0.80	1.17	421	116
JEFFERSON	21111	0.40	1.77	-1.05	-0.42	-0.80	0.02	202	49
JESSAMINE	21113	0.11	0.27	0.17	-1.10	-0.16	0.14	259	65
JOHNSON	21115	0.33	-0.18	0.01	0.27	-1.01	0.12	255	64
KENTON	21117	0.98	2.46	1.06	-0.66	0.48	-0.86	17	5
KNOTT	21119	-0.63	-0.21	0.12	-0.91	0.27	0.27	310	76
KNOX	21121	0.88	-0.47	0.01	0.48	-1.22	0.06	223	55
LARUE	21123	-0.02	-1.66	-1.05	-2.38	0.27	0.97	418	114
LAUREL	21125	-0.86	-0.48	0.56	1.12	-0.37	0.01	200	48

TABLE 2.1.-14 Continued

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
LAWRENCE	21127	-0.28	-1.13	-0.16	-1.56	0.90	0.44	364	95
LEE	21129	-1.39	-0.39	-0.27	0.63	-0.37	0.36	337	84
LESLIE	21131	-0.90	-0.48	1.06	1.96	-1.43	-0.04	187	45
LETCHER	21133	0.49	0.88	-0.49	0.36	-0.37	-0.17	138	33
LEWIS	21135	1.32	-1.09	0.67	1.37	1.33	-0.72	25	9
LINCOLN	21137	-0.21	-0.71	-1.16	0.57	0.27	0.25	305	75
LIVINGSTON	21139	0.16	-0.29	-0.77	-0.99	-1.22	0.62	394	105
LOGAN	21141	-0.42	0.22	0.34	1.26	-0.37	-0.20	130	32
LYON	21143	-1.42	-2.77	-2.54	0.93	-0.37	1.23	422	117
MC CRACKEN	21145	-0.53	0.86	0.23	-0.68	0.48	-0.07	174	37
MC CREARY	21147	1.31	1.32	0.90	0.88	-2.50	-0.38	88	22
MC LEAN	21149	-0.45	-1.80	0.51	1.45	-0.80	0.22	289	72
MADISON	21151	-0.72	-0.71	-0.71	0.91	-0.80	0.40	351	90
MAGOFFIN	21153	-1.73	-1.77	0.45	-2.09	-2.28	1.49	425	120
MARION	21155	0.08	-1.32	0.62	1.92	-0.58	-0.14	147	35
MARSHALL	21157	-0.82	-0.60	-0.44	0.86	0.05	0.19	279	69
MARTIN	21159	-1.47	0.00	0.84	-0.42	-2.50	0.71	400	108
MASON	21161	1.44	0.24	0.90	-0.08	2.60	-1.02	10	3
MEADE	21163	-0.26	-1.05	1.67	-0.55	-1.86	0.41	354	91
MENIFEE	21165	2.97	0.29	-0.88	0.06	-2.07	-0.07	175	38
MERCER	21167	0.63	1.06	0.78	2.57	-0.37	-0.94	12	4
METCALFE	21169	-0.31	-1.13	-0.32	-0.34	-0.58	0.54	385	100
MONROE	21171	2.02	-1.37	0.62	-0.09	1.97	-0.63	38	12
MONTGOMERY	21173	0.94	0.05	0.51	1.60	-1.22	-0.38	89	23
MORGAN	21175	-0.85	-1.78	-0.99	-0.87	-1.86	1.27	423	118
MUHLENBERG	21177	-0.69	-0.02	-1.05	0.23	-1.01	0.51	374	97
NELSON	21179	-0.05	-0.39	-0.88	0.19	-0.58	0.34	329	80
NICHOLAS	21181	1.87	-0.70	-1.10	3.63	-1.43	-0.46	70	19
OHIO	21183	0.23	-0.58	1.39	-0.59	-0.16	-0.06	179	41
OLDHAM	21185	-1.85	-1.31	1.34	-1.60	-0.80	0.84	412	112
OWEN	21187	2.32	-1.74	1.17	-0.86	1.33	-0.45	72	20
OWSLEY	21189	-3.14	-1.65	-0.10	-0.36	-1.65	1.38	424	119
PENDLETON	21191	1.36	-1.03	-1.65	-0.51	0.27	0.31	319	79
PERRY	21193	1.40	1.33	1.45	-1.06	0.69	-0.76	21	6
PIKE	21195	-0.83	0.62	0.01	1.16	-0.80	-0.03	190	46
POWELL	21197	2.30	-0.43	-1.54	0.25	-1.01	0.09	240	60
PULASKI	21199	0.03	-0.91	0.95	0.27	-0.58	0.05	220	53
ROBERTSON	21201	0.42	-1.25	-2.54	0.25	-1.43	0.91	416	113
ROCKCASTLE	21203	-0.09	-0.24	2.06	-0.51	-1.22	0.00	196	47
ROWAN	21205	-0.47	-0.12	0.95	-0.51	-1.22	0.29	315	78
RUSSELL	21207	-2.05	-1.13	-0.38	-1.18	-0.37	1.02	419	115
SCOTT	21209	0.86	-0.78	0.84	0.46	-1.01	-0.07	176	39
SHELBY	21211	-0.36	-0.67	-0.16	1.01	-0.37	0.11	251	63
SIMPSON	21213	-0.81	-0.67	0.23	-1.50	-0.16	0.58	390	102
SPENCER	21215	0.46	-1.77	1.34	2.87	-1.01	-0.38	90	24
TAYLOR	21217	-0.76	-1.21	0.78	-0.36	-0.16	0.34	330	81
TODD	21219	0.37	-1.15	-0.66	-0.49	0.05	0.38	344	87
TRIGG	21221	-0.54	-1.74	0.29	0.86	0.90	0.05	221	54
TRIMBLE	21223	1.16	-1.68	0.23	-0.32	-1.22	0.37	342	86
UNION	21225	0.79	0.92	-1.05	-1.06	0.05	0.07	234	59
WARREN	21227	0.05	-0.13	-0.16	0.17	-1.01	0.21	284	70
WASHINGTON	21229	0.12	-0.91	-0.82	-0.15	0.69	0.22	290	73
WAYNE	21231	0.42	-1.94	-1.10	-0.34	-1.01	0.79	408	110
WEBSTER	21233	0.42	0.47	0.17	0.15	0.05	-0.25	118	28
WHITLEY	21235	0.77	0.38	0.34	1.62	0.48	-0.72	26	10
WOLFE	21237	-1.61	-0.73	0.95	1.47	-0.16	0.02	203	50
WOODFORD	21239	-1.07	0.94	1.06	-0.36	0.48	-0.21	128	31
OHIO									

TABLE 2.1.-14 Continued

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
ADAMS	39001	1.00	-1.07	0.40	0.51	0.48	-0.26	117	15
ALLEN	39003	-0.25	0.61	-0.66	0.61	-0.16	-0.03	191	31
ASHLAND	39005	-0.03	-0.14	0.90	-0.40	-0.37	0.01	201	33
ASHTABULA	39007	-0.12	0.29	0.12	0.10	0.48	-0.17	139	21
ATHENS	39009	0.80	0.55	-0.49	-0.17	0.90	-0.32	101	14
AUGLAIZE	39011	-0.80	-0.56	-0.49	0.48	-0.16	0.31	320	57
BELMONT	39013	1.18	1.39	-0.27	-0.09	0.48	-0.54	55	8
BROWN	39015	0.68	-0.91	1.23	0.19	0.90	-0.42	80	10
BUTLER	39017	-0.48	1.28	0.62	-0.51	-0.16	-0.15	143	22
CARROLL	39019	-0.54	-0.50	-0.60	-0.86	0.05	0.49	372	63
CHAMPAIGN	39021	0.27	0.15	-0.44	-0.80	0.69	0.02	204	34
CLARK	39023	-0.22	1.32	0.29	-0.17	0.05	-0.25	119	16
CLERMONT	39025	-0.33	0.77	-0.10	-0.86	-0.58	0.22	291	53
CLINTON	39027	0.43	-0.66	0.17	-0.13	0.05	0.03	212	36
COLUMBIANA	39029	0.37	1.09	0.40	0.19	1.12	-0.63	39	4
COSHOCTON	39031	1.20	-0.05	-0.71	-0.63	-0.37	0.11	252	44
CRAWFORD	39033	0.80	0.30	-0.49	0.48	-0.58	-0.10	164	27
DARKE	39037	-1.30	-0.77	-0.71	-0.13	0.05	0.57	388	65
DELAWARE	39041	0.46	0.20	0.56	-1.20	0.27	-0.06	180	30
FAIRFIELD	39045	-0.39	0.44	0.34	-0.93	-0.37	0.18	277	49
FAYETTE	39047	0.45	-0.35	-0.49	-0.84	-0.37	0.32	323	58
FRANKLIN	39049	-0.04	1.76	1.28	-0.27	-1.86	-0.18	133	20
GALLIA	39053	0.01	-1.37	-0.99	-0.28	0.90	0.35	335	60
GEAUGA	39055	-1.13	-0.32	-1.60	-0.61	-0.37	0.81	409	69
GREENE	39057	-0.53	0.41	0.23	-0.28	-1.01	0.24	298	54
GUERNSEY	39059	0.30	-0.20	0.02	0.12	0.27	-0.22	127	19
HAMILTON	39061	-0.05	2.17	1.01	-0.23	0.27	-0.63	40	5
HARDIN	39065	0.16	-0.17	-1.27	-0.82	0.48	0.32	324	59
HARRISON	39067	0.82	0.11	-0.77	-0.13	0.69	-0.14	148	23
HIGHLAND	39071	1.46	-0.19	-0.38	-0.65	0.90	-0.23	125	18
HOCKING	39073	0.75	1.46	0.34	-0.32	-1.65	-0.12	157	24
HOLMES	39075	-1.02	-1.77	-0.44	-0.53	0.69	0.61	392	66
JACKSON	39079	1.37	0.64	2.00	0.69	0.69	-1.08	6	1
JEFFERSON	39081	0.17	1.43	1.06	-0.08	0.48	-0.61	44	6
KNOX	39083	-0.00	-0.14	1.34	-0.61	-0.16	-0.09	167	28
LAWRENCE	39087	0.16	1.44	0.56	0.69	0.69	-0.71	27	2
LICKING	39089	-0.48	0.57	0.29	-0.23	-0.37	0.05	222	38
LOGAN	39091	0.12	-0.07	0.45	-0.30	-0.58	0.08	236	40
MADISON	39097	0.45	0.45	-0.88	-0.91	-1.01	0.38	345	62
MAHONING	39099	0.18	1.52	0.62	0.02	-0.16	-0.44	74	9
MARION	39101	0.55	1.00	0.29	-0.32	0.27	-0.36	92	12
MEDINA	39103	-0.68	0.16	1.01	-1.20	0.27	0.09	241	41
MEIGS	39105	1.20	0.28	1.23	0.67	0.05	-0.69	31	3
MERCER	39107	-0.26	-1.09	-1.21	-0.68	-1.22	0.89	414	70
MIAMI	39109	-0.42	0.32	0.29	-0.47	-0.16	0.09	242	42
MONROE	39111	-0.04	-1.88	-0.05	-0.51	-0.16	0.53	380	64
MONTGOMERY	39113	-0.70	1.38	0.45	-0.21	-0.37	-0.11	160	26
MORGAN	39115	-0.69	-1.29	-0.66	-0.47	2.60	0.10	246	43
MORROW	39117	-0.67	-1.02	1.17	-1.35	0.05	0.36	338	61
MUSKINGUM	39119	0.74	0.24	0.45	-0.09	0.48	-0.36	93	13
NOBLE	39121	-0.33	-0.66	-1.32	-2.21	1.33	0.64	396	67
PERRY	39127	-0.06	-0.06	-0.77	-1.31	0.90	0.26	307	55
PICKAWAY	39129	1.05	-0.50	0.12	-0.80	-0.80	0.18	278	50
PIKE	39131	1.07	-0.11	0.90	-0.23	-0.37	-0.25	120	17
PORTAGE	39133	-1.57	0.41	-0.05	-0.65	0.48	0.27	311	56
PREBLE	39135	0.23	-1.19	0.73	-0.19	0.27	0.03	213	37
RICHLAND	39139	-0.34	0.56	0.29	-0.70	-0.58	0.16	268	47
ROSS	39141	-0.76	-0.49	0.84	0.17	-0.37	0.12	256	46
SCIOTO	39145	0.44	0.86	0.73	0.27	0.48	-0.55	53	7
SHELBY	39149	-0.77	-0.48	-0.38	-0.13	0.69	0.21	285	52

TABLE 2.1.-14 Continued

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
STARK	39151	-0.70	0.96	-0.05	0.13	0.27	-0.12	158	25
SUMMIT	39153	-1.08	1.18	0.67	-0.28	-0.80	0.06	224	39
TRUMBULL	39155	-0.30	1.34	0.78	-0.25	0.48	-0.41	84	11
TUSCARAWAS	39157	0.40	0.21	-0.99	0.02	0.27	0.02	205	35
UNION	39159	0.25	-0.08	0.56	-0.72	0.05	-0.01	193	32
VINTON	39163	0.32	-0.86	-0.10	-0.44	0.27	0.16	269	48
WARREN	39165	-0.39	0.94	1.06	-0.78	-0.37	-0.09	168	29
WASHINGTON	39167	1.06	-1.07	-0.99	0.13	-0.16	0.20	282	51
WAYNE	39169	-0.41	-1.20	-0.82	-0.89	-0.37	0.74	404	68
WYANDOT	39175	0.03	-0.67	1.17	-1.14	0.05	0.11	253	45
PENSYLVANIA									
ALLEGHENY	42003	-0.16	1.70	0.78	-0.19	0.69	-0.57	50	4
ARMSTRONG	42005	0.13	0.32	-0.44	-0.40	1.33	-0.19	131	8
BEAVER	42007	-0.44	1.51	0.84	0.44	-0.37	-0.39	86	5
BUTLER	42019	-0.09	0.57	0.17	-1.03	0.69	-0.06	181	13
CAMBRIA	42021	0.03	0.12	-0.44	0.25	0.69	-0.13	154	12
CLARION	42031	-0.37	-0.74	0.29	-0.61	-0.16	0.32	325	18
CLEARFIELD	42033	0.57	-0.11	-0.32	0.51	0.27	-0.18	134	9
ELK	42047	-0.76	-0.30	0.01	-0.53	0.05	0.31	321	17
FAYETTE	42051	1.18	0.17	0.12	0.59	1.12	-0.63	41	3
FOREST	42053	-2.75	-1.89	0.78	-1.94	0.69	1.02	420	19
GREENE	42059	1.50	-0.41	0.06	1.22	1.97	-0.87	15	1
INDIANA	42063	-0.44	-0.39	-0.82	-0.28	1.75	0.04	218	14
JEFFERSON	42065	0.45	-0.48	-0.16	0.17	0.69	-0.14	149	11
LAWRENCE	42073	0.42	0.80	-0.21	-0.27	0.05	-0.16	142	10
MERCER	42085	-0.17	0.65	-0.05	0.12	0.48	-0.21	129	7
SOMERSET	42111	-0.16	-0.77	-0.32	0.02	0.90	0.06	225	15
VENANGO	42121	2.38	0.49	0.90	0.59	-0.80	-0.71	28	2
WASHINGTON	42125	0.13	1.14	-0.05	0.06	0.48	-0.35	95	6
WESTMORELAND	42129	-0.77	0.38	-0.21	-0.51	0.69	0.09	243	16
WEST VIRGINIA									
BARBOUR	54001	0.37	-1.62	1.50	0.17	-0.80	0.08	237	34
BOONE	54005	0.65	1.52	-0.16	-0.47	-2.28	0.15	266	37
BRAXTON	54007	-0.41	-1.11	-0.21	-0.87	-0.58	0.64	397	48
BROOKE	54009	-0.20	1.88	1.01	-0.99	0.48	-0.44	75	21
CABELL	54011	0.70	1.33	1.12	0.69	-0.16	-0.74	22	6
CALHOUN	54013	0.59	-1.78	-2.49	1.41	-0.37	0.53	381	46
CLAY	54015	1.99	-0.77	1.34	2.04	-3.35	-0.25	121	29
DODDRIDGE	54017	-1.66	-1.24	0.62	3.73	1.12	-0.51	60	15
FAYETTE	54019	1.47	2.47	0.23	-0.34	-0.37	-0.69	32	7
GILMER	54021	-0.15	-1.43	-0.71	0.27	0.27	0.35	336	41
GRANT	54023	0.13	-0.91	1.89	-0.34	2.60	-0.67	34	8
GREENBRIER	54025	1.33	0.11	-0.27	1.69	-0.58	-0.46	71	20
HANCOCK	54029	-0.26	3.03	-0.32	-0.70	0.27	-0.40	85	24
HARRISON	54033	0.21	0.62	0.12	0.08	1.33	-0.47	67	19
JACKSON	54035	-0.43	-0.41	0.95	-0.11	0.48	-0.10	165	30
KANAWHA	54039	0.46	1.91	1.01	-0.21	-0.16	-0.60	46	11
LEWIS	54041	-0.39	-1.24	-1.49	2.80	-0.37	0.14	260	35
LINCOLN	54043	0.96	-0.05	1.62	0.84	-0.16	-0.64	37	9
LOGAN	54045	1.84	1.61	1.95	0.53	-2.07	-0.77	19	5
MC DOWELL	54047	1.94	1.56	1.39	1.24	-0.80	-1.07	8	2
MARION	54049	0.70	0.57	0.01	0.13	1.12	-0.51	61	16
MARSHALL	54051	0.28	1.26	0.90	0.40	0.27	-0.62	43	10
MASON	54053	-0.78	-0.94	0.45	1.88	-0.16	-0.09	169	31
MERCER	54055	0.95	0.93	1.06	0.61	-1.43	-0.42	81	22
MINGO	54059	2.96	2.00	1.67	1.64	-0.16	-1.62	3	1

TABLE 2.1.-14 Continued

ORBES COUNTY	CENSUS FIPS	Z-SCORES					HEALTH STATUS		
		AGE-ADJUSTED DEATH RATE	WHITE MALE RESPIRATORY CANCER MORTALITY RATE	WHITE FEMALE RESPIRATORY CANCER MORTALITY RATE	INFANT MORTALITY RATE	ISHEMIC HEART DISEASE MORTALITY RATE (AS % OF TOTAL DEATHS)	HEALTH STATUS INDEX VALUE	RANK WITHIN ORBES REGION	RANK WITHIN PART OF STATE IN ORBES REGION
MONONGALIA	54061	-0.25	1.30	0.51	-0.17	0.05	-0.29	107	28
MONROE	54063	0.92	-0.82	-0.71	2.55	-0.16	-0.36	94	25
NICHOLAS	54067	-0.30	-0.30	-0.21	0.13	-0.16	0.17	273	38
OHIO	54069	1.36	2.46	0.78	0.34	-0.37	-0.92	13	3
PLEASANTS	54073	2.94	-0.96	2.23	-0.38	-1.22	-0.52	58	14
POCAHONTAS	54075	1.12	-1.13	-0.38	1.98	0.05	-0.33	100	26
PRESTON	54077	-0.87	-0.55	-1.88	0.40	1.12	0.36	339	42
PUTNAM	54079	-0.24	0.11	0.56	1.60	0.48	-0.50	63	17
RALEIGH	54081	1.10	1.18	0.78	0.50	-0.58	-0.60	47	12
RANDOLPH	54083	0.32	-0.68	-0.44	-0.78	-0.58	0.43	361	45
RITCHIE	54085	-1.24	-1.27	-0.77	0.72	1.33	0.25	306	39
ROANE	54087	-0.21	-1.01	0.12	0.76	-1.65	0.40	352	44
SUMMERS	54089	0.39	-0.45	0.34	2.40	-0.16	-0.50	64	18
TAYLOR	54091	0.52	1.43	-0.55	-0.27	-1.43	0.06	226	33
TUCKER	54093	-0.09	0.82	2.11	-0.38	-0.37	-0.42	82	23
TYLER	54095	-0.94	0.03	0.12	-0.63	-0.37	0.36	340	43
UPSHUR	54097	-0.19	-1.23	0.84	0.42	0.05	0.02	206	32
WAYNE	54099	-0.27	0.73	-0.71	-0.49	-0.80	0.31	322	40
WEBSTER	54101	1.02	-0.38	-1.32	0.80	-0.80	0.14	261	36
WETZEL	54103	2.24	-0.94	1.34	0.91	-0.80	-0.55	54	13
WIRT	54105	3.13	-1.17	-1.49	-1.48	-1.65	0.53	382	47
WOOD	54107	0.52	0.06	0.17	0.50	0.27	-0.30	104	27
WYOMING	54109	1.49	0.61	2.56	0.91	-1.01	-0.91	14	4

2.2. HEALTH SERVICES

A. Introduction

In our initial effort to establish a health services availability baseline for the ORBES region, a number of conceptual issues require discussion. Specifically, the limitations of the availability concept must be elucidated.

In the literature it is generally recognized that at this time the relationship between the availability of health services, including health manpower, and the social goal of equity of access is problematic. Furthermore, there are other problems such as whether increased access to health services has a significant relationship to improved health status.

How one chooses to describe the availability of a particular service depends upon the availability of such information as well as the purposes to which this information will be put. For example, the familiar physician/population ratio when used as a measure of the availability of physician services is often also used as an indicator of a particular population's accessibility to these services. The question which must be asked is: What are the criteria for including physicians in the computation of this ratio? As discussed in the following section, the only criterion for including physicians in the measure of availability of physicians in the ORBES region is that they be active non-federal physicians (1). Other criteria often used for including physicians when calculating this ratio are the number of primary care physicians (including doctors of osteopathy) located within specified geographical boundaries who spend some portion of their time engaged in direct patient care (2).

As is true of almost all empirical indicators, there are limitations as to what can legitimately be inferred from them relative to their intended use, i.e., their validity. We will not describe these limitations for each indiator of health services availability used in this report, but will illustrate the point by reference to the physician/population ratio. At any level of analysis the physician/population ratio is a crude measure of the availability of physician services for any delimited population; this is particularly true if one is using this measure as an indicator of accessibility, which is generally defined as "...those factors that inhibit or facilitate entrance to the health delivery system..." (3). The inclusion of all active non-federal physicians in an availability (or accessibility) ratio is certainly more crude than a measure which includes only active primary care physicians who spend significant portions of their time in direct patient care. Regardless of how "physician" is defined, there remain several significant limitations to such a ratio when used as a measure of availability or accessibility. Characteristics of a provider practice as well as the geographic location of a practice are important factors facilitating or inhibiting access which are masked when one only uses the physician/population ratio. Such attributes as quality of care, hours worked, provider productivity and provider distributional issues, are other examples of underlying dimensions which are subsumed within a physician/population ratio or index. In addition, it has been suggested that organizational attributes also may inhibit the availability or accessibility of physicians to patients (4).

The mere availability of health service facilities or manpower, of course, does not ensure that these will be utilized, or utilized properly (5). Individual attributes which may predispose one to initiate a patient visit, as well as the manner in which the delivery system is utilized, are important sources of variability not reflected in crude indexes of availability. Age, race, sex, religion, level of education, national origin and attitudes regarding health and illness are some examples of individual level characteristics (6).

Other individual level characteristics which enable and condition one's use of the health system are such things as income; type and extent of third party coverage, e.g., Blue Cross-Blue Shield, private insurance, Medicaid, Medicare, prepayment plans such as a Health Maintenance Organization (HMO); and amount of out-of-pocket expense required.

Delivery system properties also impact upon one's interpretation and use of availability measures. The volume and distribution of resources, e.g., labor, capital, urban and rural location, are important system properties which constrain the use of much of the data on availability. Another system dimension of interest is that of organization, the manner in which the system components are structured, coordinated and controlled. Such features as patient travel time, waiting time, number of different providers seen per illness episode, and how one is treated, are some examples of indicators of this dimension.

Another obvious factor constraining interpretation of availability and accessibility measures is the need for care, both as perceived by the individual and as evaluated by normative medical criteria. There are several indexes for measuring utilization and some of these have attempted to incorporate normative medical judgments regarding level of need or appropriateness of resource use by the individual (7). In this regard a basic issue concerns the relationship among the need for care, the provision of more health services and improved access to these services. Restating this premise, the question becomes whether, and to what extent, improved access necessarily leads to a better state of individual health without taking into consideration other factors such as individual lifestyle, one's health habits and the quality of one's physical and social environment. Several recent studies have investigated the nature of this relationship; in general the results have been negative (inverse) or inconclusive (8). One such study by Gittelsohn in Vermont implies that

"...MUA (medical underserved area) and MSA (medical shortage area) residents use medical services at about the same rate as residents of amply served areas and that outcomes, as measured by mortality, are similar" (9). Criticism of this study relates to the crudeness of using mortality rates as an indicator of the health status of a population as well as several related problems of definition (10). It is debatable as to what extent increasing the provision of health services beyond some minimum level, and improving access to these services, will lead to a reduction in disability days or symptom reporting for a specified population, irrespective, as suggested above, of other considerations.

The consequences of the impact of the environment and personal health habits upon one's state of health are put forth as one interpretation to explain the generally inverse findings between increased access to health services and improved health status. A second implication of these studies is that "...unrestricted access to medical care actually causes more sickness and is another example of social iatrogenesis" (11). A third plausible explanation is that "...the inverse relationship between improved access and lower perceived health status is desirable because people's more realistic knowledge of their health status may, in the long run, lead to improved health" (12). In effect, the relationships between utilization of health services and individual health status are not clearly understood at the moment (13).

As to whether there are excess hospital beds, and the extent to which this situation, if true, contributes to rising hospital charges, are highly ambiguous and controversial issues. Although a recent study concludes that there is an excess nationally of non-federal short-term general hospital beds, it is recognized that this may not be the case for local areas or regions (14). There appear to be two major problems with such studies. (a) There is a bewildering array of definitions used when compiling the count of available hospital beds. Some studies count only current beds in place, while others include beds under construction or approved for construction. Also, beds set aside for one purpose, e.g., short-term use, may be converted to long-term use depending upon the demand, reimbursement requirements from third party payers and regulatory guidelines. (b) The other major issue here concerns the extent to which excess hospital beds contribute to increased hospital costs. Hospital occupancy and utilization rates are two of the principal criteria used to determine the "appropriate" number of beds per 1,000 population. As might be expected, these standards are the source of considerable debate as to the manner by which they are derived and their relation to excess bed capacity (15).

It was estimated that in 1976 the approximate national average of non-federal short-term general hospital beds was 4.4/1,000 population (16). Again, this is only an estimate and this average depends upon varying definitions of bed use. The excess bed capacity estimates derived from such enumerations also are dependent upon fluctuating values regarding "acceptable" occupancy rates and projected utilization rates.

B. Definition of Variables

Raw data utilized in determination of the health services availability index were collected from computer tapes listed in the Area Resource File: Tape Documentation as of June, 1977, U.S. Department of Health, Education and Welfare, Bureau of Health Manpower, Manpower Analysis Branch. Individual indices are listed as follows.

1. Physicians: Col-Col/0244-0249
   1972 Active, non-federal physicians/100,000 population
   Source: Posted, American Medical Assoc. Dist., 1972
   December, 1975.

2. Dentists: Col-Col/0378-0381

   1972 Licensed dentists/100,000 population

   Source: Dental Register, 1972

   February, 1976.

3. Nurses: Col-Col/0590-0595

   1972 Active registered nurses employed in nursing/100,000 population

   Source: American Nurses Assoc. Tape, 38-42, 1972

   September, 1974.

4. Pharmacists: Col-Col/0548-0553

   1973-74 Active pharmacists for 1974/100,000 population

   Source: 73-74 Active Pharmacists Tape, 1974

   April, 1976.

5. Beds: Col-Col/0181-0181

   1968 number of hospital beds/100,000 population

   Source: American Medical Assoc. Dist. Phys., 1968

   December, 1975.

6. Mean Z Score: The arithmetic mean of Z scores computed for all indices: physicians, dentists, nurses, pharmacists, beds.

C. Availability of Health Service Providers and Hospital Beds in the ORBES Region

Cognizant of the limitations discussed above we proceeded to adopt a method whereby it is possible to directly and validly compare a ranking for each county in the ORBES Region for each index specified, as well as an overall measure which ranks counties across each index, i.e., a cumulative index. The method consists of converting the raw data for each index into standard (Z) scores, then computing an arithmetic mean Z score for all indices for each county in the ORBES Region (17).

The first step was to convert the raw data for each county into Z scores; this was done in the usual manner as described in Section 2.1. An approximation to the normal distribution for each Z score distribution was verified through graphing and measures of skewness and kurtosis. That is, the distribution of health services personnel and hospital beds in the ORBES Region for 1974 approximates a normal curve pattern where most counties cluster at the mean and very few examples exceed ± 2 standard deviations on any one measure.

Standard (Z) scores were computed for each index with each distribution having a mean of 0 and a standard deviation of 1. The Z scores were then summed across the indices and an arithmetic mean Z score was computed for each county.

In addition to the assumption of normally distributed Z scores there are several other assumptions and premises which should be made explicit:

1) There is no implication that the mean Z score for each distribution constitutes an acceptable standard; Z scores above or below the mean illustrate only the variability of any one distribution, i.e., one county has more or less of a certain category than another.

2) The computation of the mean Z score in this instance assumed an equal weighting for each provider group and hospital beds in its contribution to the final average score. It is not clear how one would determine the criteria and specific values by which to measure and judge the relative worth (weight) of each of these variables in a weighted index.

3) A third and more problematic assumption concerns the relationship between the availability of providers and hospital beds in a particular region and the health status of residents therein. As discussed above, the familiar physician/population ratio is a very crude measure of

availability; also the concept of "health" or "health status" is very difficult to adequately conceptualize, particularly operationally. The manner by which one utilizes and gains access to health system resources are considerations at least as critical as the availability of these resources. Finally, it has been recognized that environmental factors and preventive efforts play a very important role in individual health status.

Both the mean Z scores and the Z scores for each variable were rank-ordered. The scores were then categorized into deciles using the appropriate standard deviations as the cutoff points, e.g., $Z = \pm 1.28$ gives the upper and lower boundaries for the highest and lowest decile of Z scores. These were then coded into a map of the ORBES Region for each county (see Section D). The mapping illustrates the geographical distribution (variability) of the various provider groups, and hospital beds, by decile. Health Systems Agency (HSA) boundaries within the ORBES Region were then drawn and it is at this geographic level that comparative analysis proceeded.

D. Discussion

As stated above, the mean Z scores and the Z scores for each health service availability variable were rank-ordered so as to categorize them into deciles. The appropriate Z score cutoffs were computed for each decile. Table 2.2.-1 lists the Z score ranges determined for each decile.

To interpret the availability data a number of tables and maps were prepared. Table 2.2.-2 lists Z scores and the accompanying deciles of all the ORBES counties. Populations by county are listed alphabetically within each health service area of a Health Systems Agency (HSA), the offical regional health planning body established under PL93-641 (The National Health Planning and Resources Development Act of 1974). Figure 2.2.-1, Health Services

Areas in the ORBES Region, shows the boundaries and designated number of each HSA. The majority of HSA boundaries in the ORBES Region are intrastate; however, three of the service areas cross state boundaries. These are: HSA-10 (Illinois); HSA-11 (Illinois); HSA-1 (Ohio).

Tables 2.2.-3 and 2.2.-4 were prepared to illustrate more precisely those counties in the ORBES Region which were found to be in the highest and lowest decile of health services availability (Z = ± 1.28). Counties and populations in these tables, as in Table 2.2.-2, are arranged alphabetically by HSA.

From Tables 2.2.-2, 2.2.-3 and 2.2.-4 a series of maps were constructed to identify those counties in the ORBES Region with Z scores falling within the 1st and 2nd (lower) and the 9th and 10th (higher) decile ranges. (These deciles approximate ± 1 standard deviation from the mean and, in general, represent lower and higher extremes of the health services availability index).

Figures 2.2.-2 through 2.2.-7 show the geographical distribution (variability) of each of the six indices used in the study: physicians, dentists, pharmacists, nurses, beds and mean Z score of all indices.

Examination of the maps and tables offers the following observations.

1) For the most part the data reflects Z scores which are directly correlated with population. Counties with higher numbers of residents tend to have higher Z scores associated with them. Those counties which are less populated have Z scores which tend to be much lower. In many instances then, counties with larger populations tend to rank higher on the health services availability index, while the less populated counties are often found to rank in much lower deciles.

2) The maps indicate that such counties are frequently in close proximity. That is, larger metorpolitan counties tend to be ranked in higher deciles while immediately surrounding or nearby counties might show up to be ranked in much

lower deciles of health service availability. Certain exceptions do exist and are evidenced by extreme clustering (e.g., higher availability of services in western Pennsylvania and lower availability of services in northeastern Kentucky and northcentral West Virigina).

3) The data reflects that physician availability is much higher in the more populated counties.

4) Z scores for dentists and pharmacists tend to be higher in many smaller, less populated counties and do not necessarily follow the tendency of physician availability in larger populated counties.

5) Z scores for nurses availability vary by county and by state: however, they seem to have a positive correlation with the availability of physicians and beds. Z scores for nurses show high decile clusters within a region encompassing eastern Ohio, southwest Virigina and western Pennsylvania.

6) An exceptional large number of counties in the ORBES Region show low decile ranges for bed and nurse availability.

7) Counties in the lower decile of health services availability tend to range south from the Ohio River throughout the states of Kentucky and West Virignia. These counties are usually less populated and/or are located in or near mountainous areas of these states.

8) Low dentist and pharmacist availability is reflected by Z scores of several counties in West Virignia and HSA-2 (Kentucky).

E. Two Government Concepts and Procedures for Designating Shortage Areas

There are several more refined procedures for comparing the availability of health services, including manpower, as measured by specified criteria for geographically delimited populations. Two of the indices are: the "medically underserved area" (MUA), as determined by an Index of Medical Underservice

(IMU), (18) and the "health manpower shortage area," established by comparison of existing members of health manpower with a designated area to varying levels of population, as well as other criteria (19a).

The Concept of a Medically Underserved Area

The Health Maintenance Organization (HMO) Act of 1973 (P.L. 93-222) requires that funding priority be given to HMO's that will draw not less than 30 percent of their membership from medically underserved areas or populations (20). Public and private nonprofit entities such as community health centers also may qualify for such funding. To designate areas as being medically underserved, a weighted Index of Medical Underservice is computed on the basis of the following indicators (21).

1) ratio of primary care physicians to population;
2) infant mortality rate;
3) percentage of the population 65 years of age or over;
4) and percentage of the population with family income below the poverty level.

The list of counties, minor civil divisions, census county divisions and census tract areas designated as "medically underserved areas" from the initial compilation of the IMU can be found in the Federal Register (18b). Health System Agencies (HSA's) are eligible to recommend changes in the list which reflect more local considerations; in addition, these lists are periodically revised on the basis of changes in the indicator values or adjustments in the cutoff levels. The initial cutoff value for designating areas as medically underserved was 62.0, the 1975 median IMU score of all U.S. counties, which included approximately 25 percent of the total U.S. population (22).

An upcoming categorization of all U.S. counties using the Index of Medical Underservice will occur during the fall of 1980. No major changes in the manner by which the Index is constructed or applied are anticipated by that time. Assuming this to be the case, the principal effect will be to reassign the counties above or below a different median cutoff value.

As with almost any index, the IMU has associated strengths and weaknesses. All state and areawide comprehensive health planning agencies (in 1975) were asked to submit comments and recommendations on the initial list of MUA's (counties); the index itself, together with the method of computation; its application to local area data; and suggested additions or deletions from the list based upon better data applicable to the local area (23).

The varying geographical boundaries mentioned above anticipate one of the criticisms of this index: two of the indicators are available nationally only at the county level while the other two (poverty and age indicators) are found at the census tract and civil division levels.

One of the primary effects of this determination, in principle, is to make these counties eligible for the assignment of National Health Service Corps physicians for a two year period.

If we assume future changes in the nature of energy production in the ORBES area, as suggested by the various scenarios presented in this report, several consequences regarding the availability of health services in this region logically follow:

(1) The availability of health care providers and facilities is stimulated by changing population levels and resulting market forces as is true for most other businesses.

(2) When economic development in an area reaches a certain level concomitant with increasing population levels, health care providers as well as public and private monies to build health care facilities will follow. Prior to 1978, the Miners' Clinics, organized by the United Mine Workers and staffed by physicians on retainer, are a good example of this process.

(3) The premise is that, regardless of the mix of new energy production sources which may occur in the ORBES region over the next several years, economic and population growth will occur.

If the primary shift in energy production is toward coal mining, the nature of this source of energy production, in addition to the growing or shifting population, will further stimulate demand for health care services. On the supply side, we can assume, at some point, development of economic incentives sufficient to result in relocation or redistribution of health care providers from existing urban or semi-urban areas.

(4) There has been some increase in the number of physicians who are opting for direct entry into private practice in medically underserviced areas which fulfills their National Health Service Corps obligations. This process has somewhat greater potential for providing these areas with lasting medical care than does the temporary physician assignment to an area in order to complete Health Service Corps requirements. While the National Health Service Corps was designed in part to provide physicians for rural areas, which characterizes many of the underserviced areas designated by the IMU, a recent study has characterized the Corps as "responding to emergency situations with emergency solutions..." (24).

The failure of rural areas and small communities to attract and/or retain physicians is a well recognized problem. Governmental solutions, such as the National Health Service Corps, state loan forgiveness programs on the basis of geographic location of practice, or more direct governmental intervention as in England where certain geographic areas are closed to new physicians, have not operated as successfully as expected.

Another nascent strategy relative to this problem is to identify "...Those physicians who are most likely to have some proclivity for rural practice and removing the barriers to establishing their practices in areas of physician scarcity" (25).

Health Manpower Shortage Areas

Section 332 of the Health Professions Educational Assistance Act of 1976 (P.L. 94-484), required the Secretary of HEW to establish, by regulation,

> ...criteria for the designation of health manpower shortage areas and subsequently designate areas based upon these criteria. Public or nonprofit entities in (or with a demonstrated interest in), the areas designated pursuant to these criteria will be eligible to apply for the assignment of members of the National Health Service Corps to provide health services in or to the areas... (26)

These criteria are used to designate not only geographic areas as shortage areas but are applicable also to population groups, medical facilities and other public facilities (27). The criteria have been developed separately for each type of health manpower, which includes: primary medical care, dental, psychiatric, vision care, podiatric, pharmacy and veterinary manpower. This is the current (1978) range of manpower considered in the evaluation, but shortages of other types are being explored as well. The specifics of any one criterion for determining relative levels of manpower shortage are not be construed as adequacy levels. Thus there may very well be areas, facilities, population groups, which do not meet criterion levels yet have inadequate health manpower. Recommendations from Health System Agencies, state health planning and development agencies, and governors, also may be taken into consideration in the procedures for designating shortage areas. The criteria include methods for comparing the degree of shortage in any two areas, with priority given to those areas with the greatest shortage. The definitions of the criteria, the computational procedures and cutoff levels for each type of manpower are given in the Federal Register (19).

Summary of Comparisons Between Medically Underserved Areas (MUA) and Manpower Shortage Areas (28)

One shortcoming of the above approaches to shortage area designations was that two separate lists existed each with distinct criteria for physicians and dentists. Secondly, the reliance on county level data, given its availability, does not inherently define a rational service area, particularly in metropolitan areas. Another major shortcoming of the initial manpower shortage area procedures was an over-reliance on practitioner/population ratios which tended to mask differences among areas, as well as such problems as access to services. The MUA procedures avoid this problem to some extent by including three indicators in addition to a practitioner/population ratio (see discussion above). However, the MUA designation procedures do not attempt to define "rational non-county service areas or to take into account contiguous area conditions" (29). The difficulties in designating sub-county MUA's were pointed out earlier in this section.

The Health Professions Educational Assistance Act of 1976 required the development of new criteria for designating health manpower shortage areas (30). With the development of these new criteria, "...all areas designated as primary care manpower shortage areas will also be considered designated as medically underserved areas (MUA's). Other areas which qualify using the Index of Medical Underservice will continue to be designated as MUA's, however, whether or not they meet the primary care HMSA criteria" (31).

A key issue not fully considered in the process of designating shortage areas is the difference between need and demand for care. The Bureau of Health Manpower considers the practitioner/population ratio a need factor, with the population being modified to reflect demand and utilization considerations.

> In general, our policy is to designate shortage areas based primarily on need, with the demand considerations to be taken into account in the process of considering applications to the NHSC for placement of personnel (or to BCHS for grant funds to be used in MUA's)(32).

In considering the availability of health manpower particularly those who deliver direct medical services, the mid-level practitioners, specifically physician's assistants and nurse practitioners, must be included. Formal training programs for these practitioners began in 1965 with the initiation of the Physician Assistant (P.A.) program at Duke University. The original goals for this movement, particularly for P.A.'s, were to alleviate (33):

1) the reported physician shortage in the U.S.;
2) the reported maldistribution of U.S. physicians; and
3) the problems linked to overspecialization of physicians.

In 1976, the American Academy of Physicians' Assistants, Association of Physician Assistant Programs, conducted a survey of 4,963 persons who had graduated from an American Medical Association approved program in primary care, surgery, urology or orthopedics, and/or had passed the National Certifying Examination for the Primary Care Physician Assistant (34). Table 2.2.-5 describes the geographic distribution of the 3,167 respondents to that survey, by region and state.

The use of these two mid-level practitioners has been advocated as a means of improving access to primary health care and increasing the amount of primary care provided. One recent study suggests that these "physician extenders" do appear to be reducing inequities in poor physician specialty distribution and in geographic location, as most respondents to this survey report they work in primary care practices and initially have located in more rural, low income counties (35).

Health Planning Using the IMU

The use of the Index of Medical Underservice (IMU) for health planning purposes presents multiple contingencies and limitations. Some of these will be summarized here.

The first serious limitation of the Index is that the concept "medical underservice" has yet to be defined. In general, of course, the reference is to some judgment about the relative lack of available health services in relation to some standard or criterion, but it is precisely the latter which has not been made explicit. One health services researcher has proposed three criteria for consideration (36).

1) Scarcity of services may be measured in terms of the number of services available to a population or area compared to the average number of services available in a region or the nation.

2) Scarcity of services may be measured by some judgment about the relationship between the demand for services in a particular area and the availability of services to meet that demand.

3) Finally, services may be measured by the relationship between the availability of services and some estimate of need for health services.

None of these criteria, nor any other, were explicitly considered in the development of the Index as it now stands. During the process of creating the Index, the researchers were frustrated by disagreements among health experts about how to define "medical underservice." However, there did appear to be expert consensus regarding their assessments of relative underservice while disagreeing as to the meaning of this construct (37). The mathematical model developed to predict expert assessment of relative underservice for specific areas was built upon this consensus notion, ultimately using the four variables described on page 2.2-11. The choice of using these four variables was predicted more on pragmatic grounds than upon conceptual and theoretical clarity related to clearly designated outcomes or benefits (38).

A second major limitation of the Index for planning purposes is that the relationship between health resources (or additional resources) and improvement in personal health status is rather unclear beyond the health benefits resulting from increases in the standard of living and mass applications of preventive measures. In addition, "The development of a model or index that would relate changes in health status to changes in availability, or other system components, is at this time, beyond the state of the art in health services research" (39). At this point one must not succumb to the empiricist notion that the availability (or some other services concept such as accessibility) of services can be considered a direct index of health status.

Thirdly, it is difficult to adequately interpret the values of the Index when applied to local conditions. Any one Index value may be obtained by multiple combinations of values for the individual variables.

> In addition, given the weighting system applied to the four variables, areas can quality as medically underserviced on the basis of extreme values for percentage of persons below poverty and percentage over age 65 even though medical services are abundant and infant mortality is relatively low. Conversely, communities that have serious shortages of primary care physicians, or perhaps none at all, would not qualify as medically underserviced if they have relatively low proportions of the aged or poor (40).

In the development of the Index, concepts closely related to "underservice" such as utilization patterns or accessibility measures were not considered. Most often, data for such measures for small areas just do not exist, yet it seems clear that the availability concept is at too crude a level when considering its relationship to changes in health status. In this regard, an interim alternative to the Index for Medical Underservice, using data and the methodology of the Health Interview Survey, has been proposed (41).

The last limitation of the Index presented here has to do with its usefulness for regional or local health planning. Given the state of the art as roughly presented above, it appears that the attempt to characterize an entire area or region on the basis of a single index value would probably mask significant differences among areas.

> Most of the critical decisions about the allocation and organization of health resources at the regional and local level require the use of relatively detailed community profiles rather than indexes. For planning purposes, then, the Index of Medical Underservice is considerably more useful when it is disaggregated than when it is used as a measure of medical underservice (42).

The usefulness of a concept such as "medical underservice" should reflect its meanings and implications for policy makers and for those most likely affected by such policies. This point was specifically recognized by the health services research team which developed the Index.

> Although it may be possible to validate the Medical Underservice Index, it will be extremely difficult to evaluate whether additional personal health services did produce more benefits at sites designated as underserviced than at undesignated sites. This is because the objectives and benefits were never made explicit. Evaluation of the Index of Medical Underservice can only be done in terms of a standard established apart from the current Index (43).

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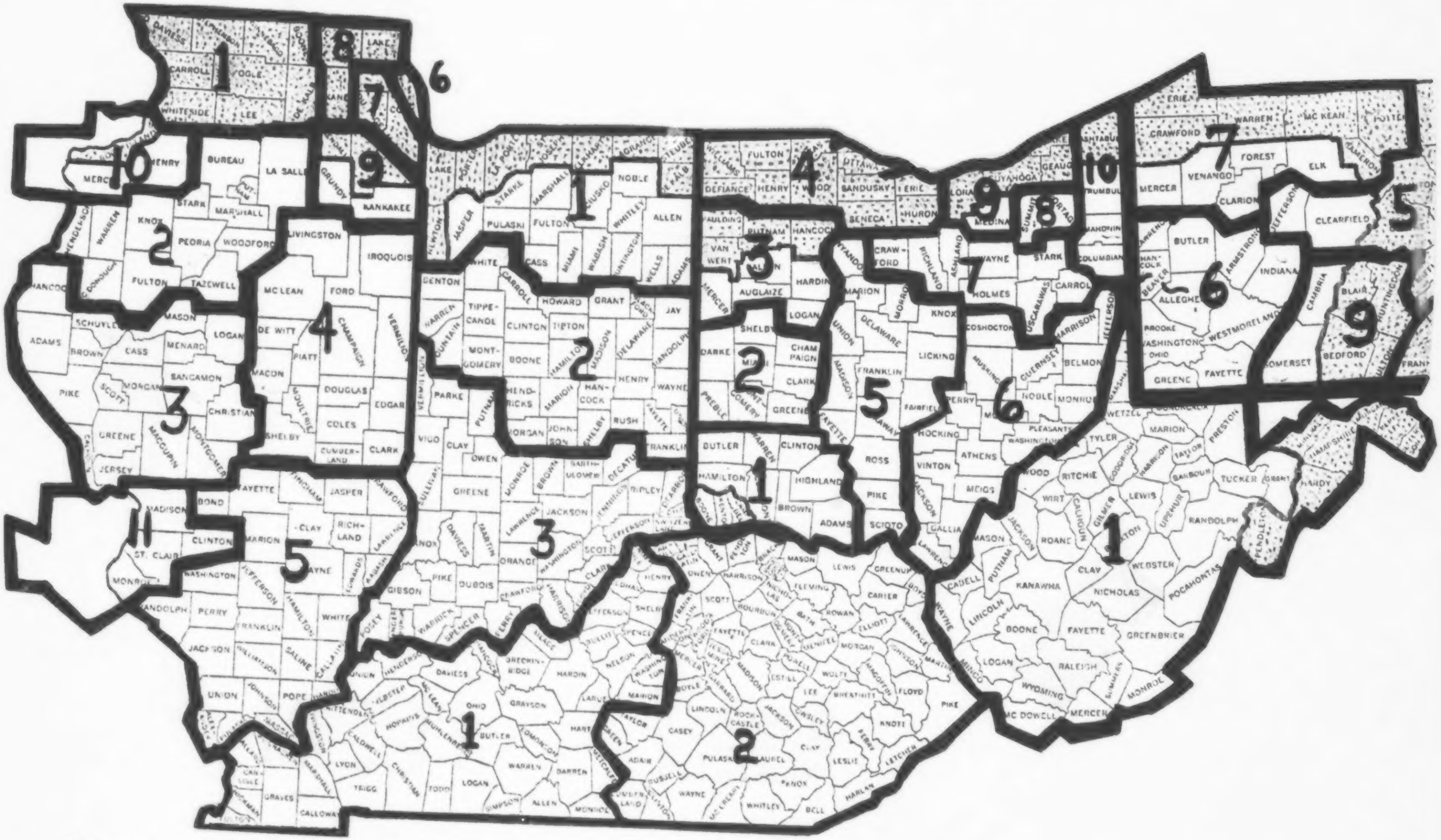
FIGURE 2.2.-1
Health Service Areas in the Ohio River Basin Energy Study Region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CARROLL
OGLE
WHITESIDE
LEE
HENRY
BUREAU
LA SALLE
MARSHALL
STARK
KNOX
PEORIA
WOODFORD
WARREN
FULTON
TAZEWELL
GRUNDY
KANKAKEE
LIVINGSTON
IROQUOIS
MC LEAN
FORD
DE WITT
CHAMPAIGN
VERMILION
PIATT
MACON
DOUGLAS
EDGAR
MOULTRIE
COLES
SHELBY
CUMBERLAND
CLARK
HANCOCK
MASON
SCHUYLER
MENARD
LOGAN
ADAMS
BROWN
CASS
SANGAMON
PIKE
SCOTT
MORGAN
CHRISTIAN
GREENE
MACOUPIN
MONTGOMERY
JERSEY
MADISON
BOND
FAYETTE
JASPER
CLAY
RICHLAND
CLINTON
MARION
ST. CLAIR
MONROE
WASHINGTON
WAYNE
RANDOLPH
PERRY
FRANKLIN
HAMILTON
WHITE
JACKSON
SALINE
UNION
JOHNSON
POPE
JASPER
STARKE
PULASKI
FULTON
MARSHALL
KOSCIUSKO
NOBLE
ALLEN
WHITLEY
WABASH
HUNTINGTON
MIAMI
CASS
WHITE
WELLS
ADAMS
BENTON
WARREN
TIPPECANOE
CARROLL
HOWARD
GRANT
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CLINTON
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BOONE
HAMILTON
MADISON
DELAWARE
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JACKSON
SULLIVAN
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ORANGE
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GIBSON
PIKE
DUBOIS
SPENCER
WARRICK
POSEY
WILLIAMS
FULTON
DEFIANCE
HENRY
WOOD
OTTAWA
SANDUSKY
ERIE
SENECA
HURON
PAULDING
PUTNAM
HANCOCK
VAN WERT
ALLEN
HARDIN
MERCER
AUGLAIZE
LOGAN
SHELBY
DARKE
CHAMPAIGN
CLARK
MIAMI
PREBLE
MONTGOMERY
GREENE
BUTLER
WARREN
CLINTON
HAMILTON
HIGHLAND
BROWN
ADAMS
CRAWFORD
RICHLAND
ASHLAND
WAYNE
STARK
CARROLL
MARION
MORROW
KNOX
HOLMES
TUSCARAWAS
HARRISON
JEFFERSON
UNION
DELAWARE
LICKING
COSHOCTON
FRANKLIN
MADISON
FAIRFIELD
MUSKINGUM
GUERNSEY
BELMONT
FAYETTE
PERRY
NOBLE
MONROE
PICKAWAY
ROSS
HOCKING
PLEASANTS
WASHINGTON
VINTON
ATHENS
PIKE
JACKSON
MEIGS
SCIOTO
GALLIA
LAWRENCE
CUYAHOGA
GEAUGA
MEDINA
SUMMIT
PORTAGE
TRUMBULL
MAHONING
COLUMBIANA
ASHTABULA
ERIE
CRAWFORD
WARREN
MC KEAN
POTTER
MERCER
VENANGO
FOREST
ELK
CLARION
CAMERON
JEFFERSON
CLEARFIELD
BUTLER
ARMSTRONG
INDIANA
BEAVER
ALLEGHENY
LAWRENCE
BROOKE
WASHINGTON
OHIO
WESTMORELAND
CAMBRIA
BLAIR
HUNTINGDON
GREENE
FAYETTE
SOMERSET
BEDFORD
FULTON
WETZEL
MARION
TYLER
PRESTON
WOOD
RITCHIE
DODDRIDGE
HARRISON
TAYLOR
BARBOUR
TUCKER
GRANT
HARDY
WIRT
GILMER
LEWIS
UPSHUR
RANDOLPH
PENDLETON
HAMPSHIRE
MASON
JACKSON
ROANE
CALHOUN
CLAY
BRAXTON
WEBSTER
POCAHONTAS
CABELL
PUTNAM
KANAWHA
NICHOLAS
LINCOLN
BOONE
FAYETTE
GREENBRIER
WAYNE
LOGAN
RALEIGH
MINGO
WYOMING
SUMMERS
MONROE
MC DOWELL
MERCER
MASON
LEWIS
GREENUP
BOYD
CARTER
FLEMING
ROWAN
ELLIOTT
LAWRENCE
SCOTT
BOURBON
BATH
OWEN
HARRISON
NICHOLAS
HENRY
SHELBY
FAYETTE
CLARK
MONTGOMERY
MENIFEE
MORGAN
JOHNSON
MAGOFFIN
FLOYD
PIKE
ESTILL
POWELL
WOLFE
LEE
BREATHITT
KNOTT
MADISON
JACKSON
OWSLEY
PERRY
LETCHER
LINCOLN
ROCKCASTLE
CLAY
LESLIE
HARLAN
CASEY
PULASKI
LAUREL
KNOX
BELL
ADAIR
RUSSELL
WAYNE
MC CREARY
WHITLEY
CUMBERLAND
CLINTON
MARION
TAYLOR
GREEN
METCALFE
MONROE
HART
LARUE
HARDIN
GRAYSON
BRECKINRIDGE
HANCOCK
DAVIESS
HENDERSON
UNION
WEBSTER
MC LEAN
OHIO
HOPKINS
MUHLENBERG
BUTLER
EDMONSON
WARREN
BARREN
CALDWELL
CHRISTIAN
TODD
LOGAN
SIMPSON
ALLEN
LYON
TRIGG
MARSHALL
GRAVES
CALLOWAY
LIVINGSTON
CRITTENDEN
CARLISLE

Footnote: Health Service Areas Designated Under the National Health Planning and Resources Development Act of 1974, DHEW Publication No. (HRA) 78-14014, U.S. Dept. of H.E.W. Public Health Service Health Resources Administrator, Bureau of Health Planning & Resources Development

FIGURE 2.2.-2

Health Services Availability - Physicians
Z Score Distribution

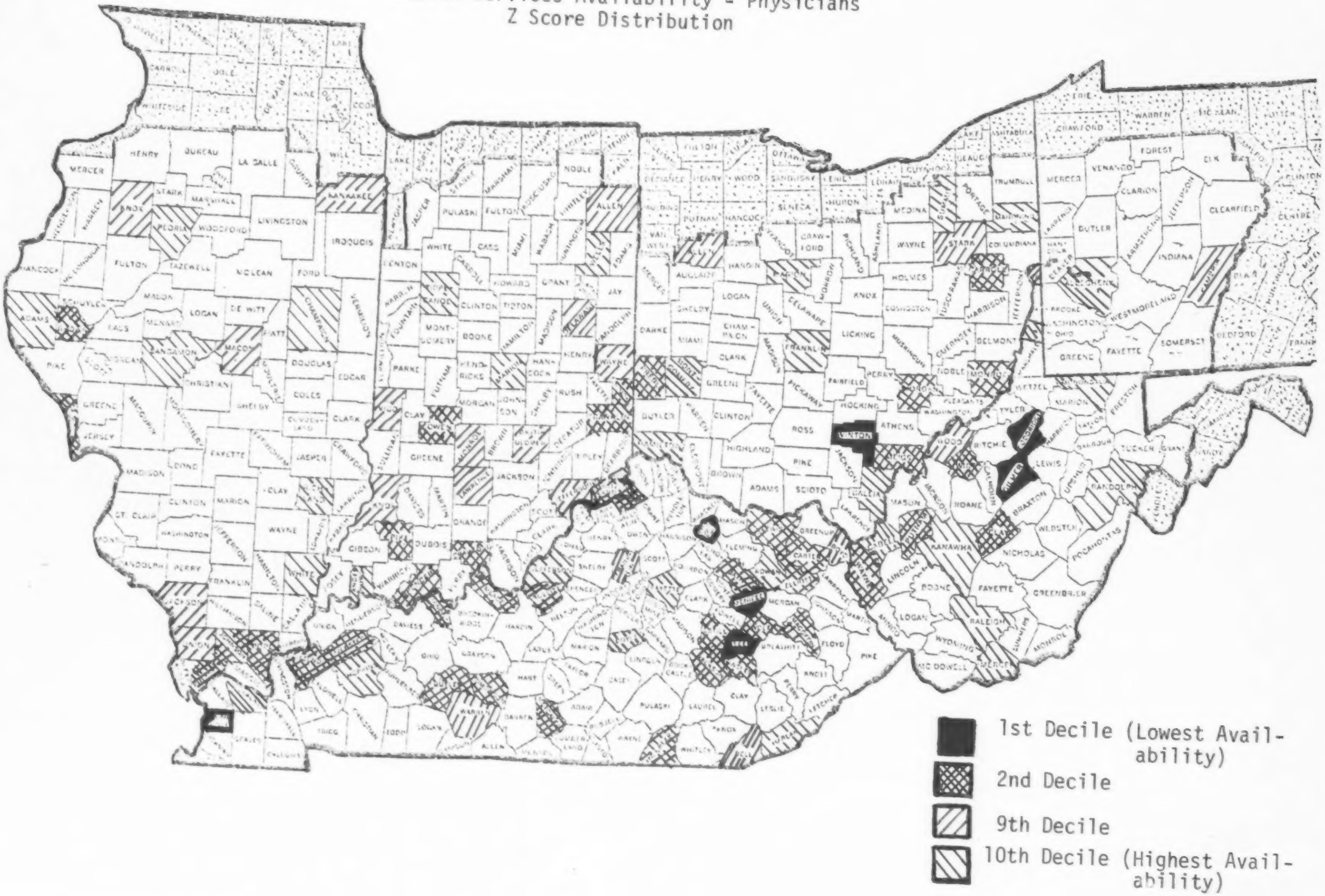

■ 1st Decile (Lowest Availability)
▦ 2nd Decile
▨ 9th Decile
▧ 10th Decile (Highest Availability)

FIGURE 2.2.-3

Health Services Availability - Dentists
Z Score Distribution

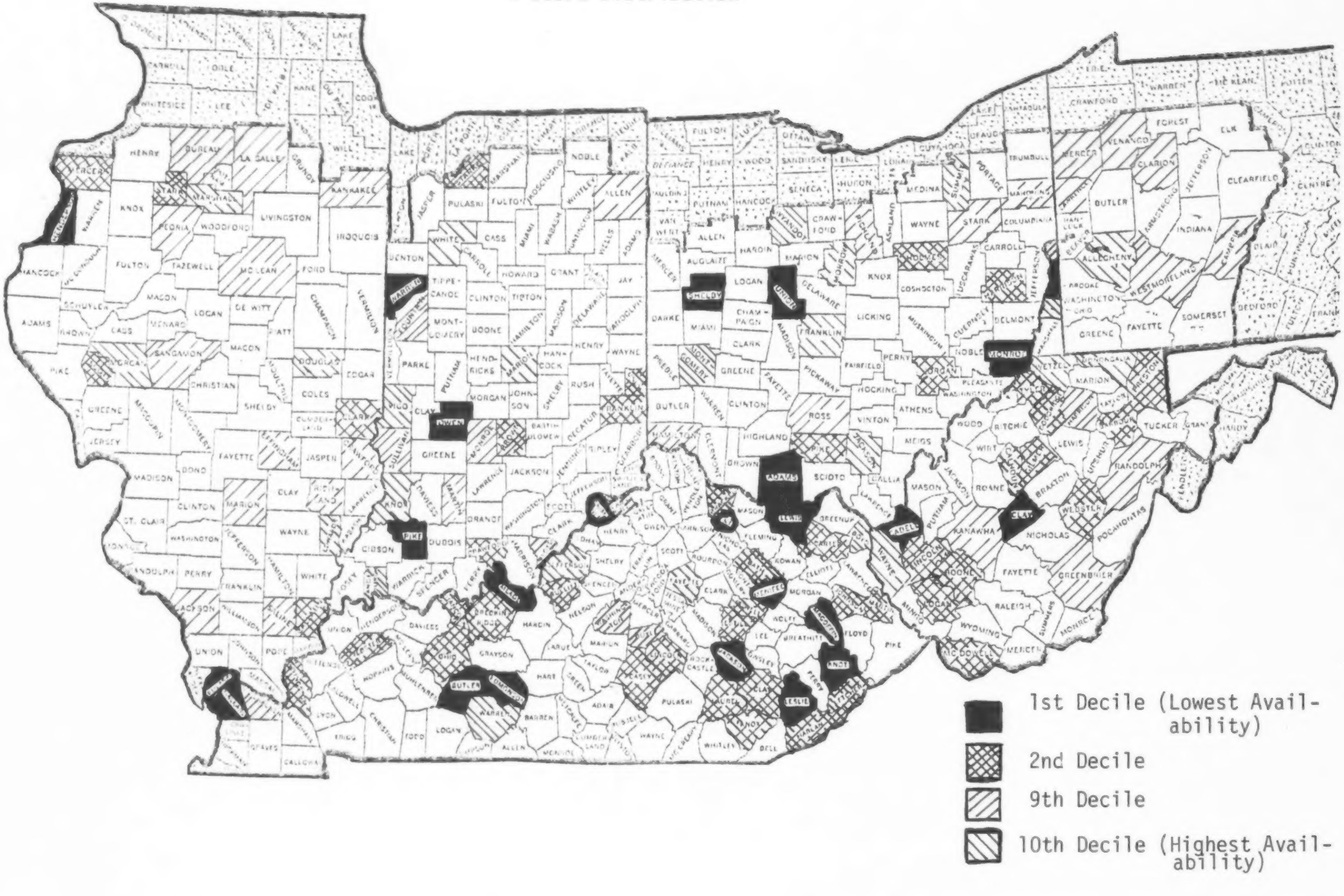

■ 1st Decile (Lowest Availability)
▩ 2nd Decile
▨ 9th Decile
▧ 10th Decile (Highest Availability)

FIGURE 2.2.-4

Health Services Availability - Pharmacists
Z Score Distribution

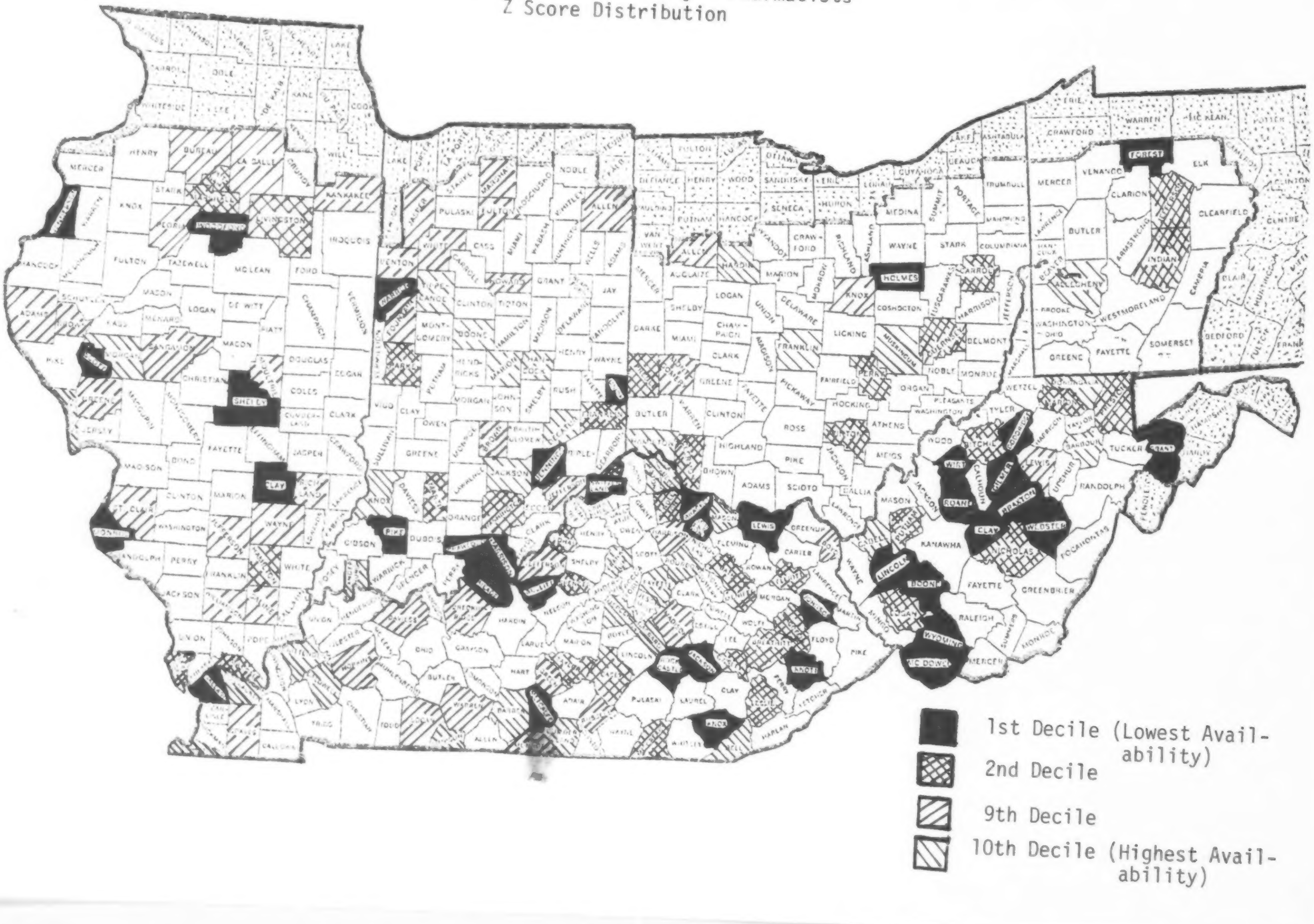
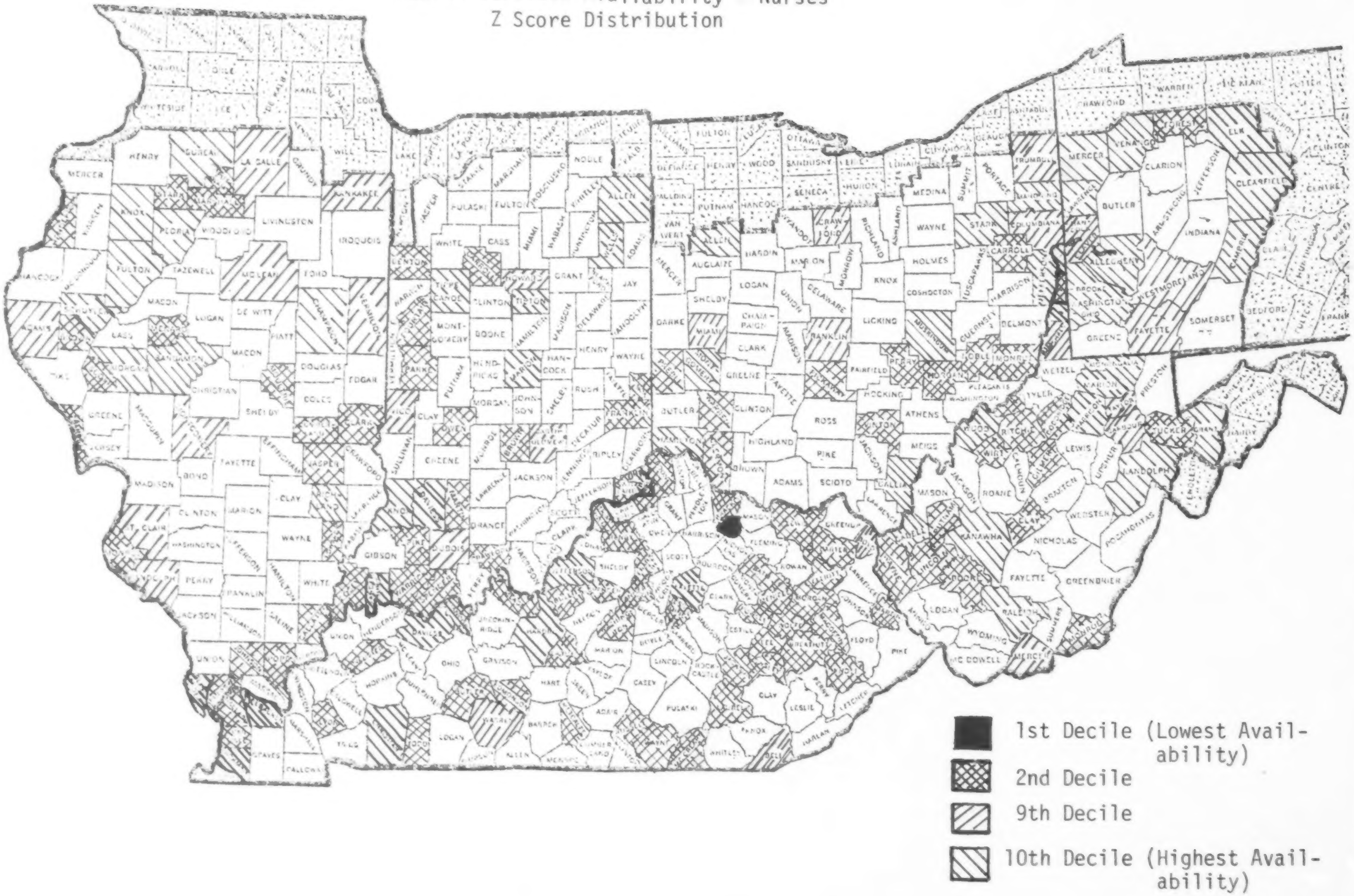

■ 1st Decile (Lowest Availability)
▩ 2nd Decile
▨ 9th Decile
▧ 10th Decile (Highest Availability)

FIGURE 2.2.-5

Health Services Availability - Nurses
Z Score Distribution


■ 1st Decile (Lowest Availability)
▩ 2nd Decile
▨ 9th Decile
▧ 10th Decile (Highest Availability)
MERCER
HENRY
BUREAU
LA SALLE
GRUNDY
KANKAKEE
LIVINGSTON
IROQUOIS
KNOX
PEORIA
WOODFORD
FULTON
TAZEWELL
MCLEAN
FORD
HANCOCK
MACON
LOGAN
DE WITT
PIATT
CHAMPAIGN
VERMILION
DOUGLAS
EDGAR
COLES
CHRISTIAN
SHELBY
GREENE
JERSEY
MADISON
BOND
FAYETTE
CLAY
JASPER
CLINTON
MARION
WAYNE
WASHINGTON
PERRY
FRANKLIN
HAMILTON
WHITE
JACKSON
SALINE
UNION
LAKE
PULASKI
FULTON
MARSHALL
KOSCIUSKO
NOBLE
ALLEN
WHITE
CASS
MIAMI
WABASH
WHITLEY
HUNTINGTON
GRANT
JAY
BOONE
CLINTON
TIPTON
HAMILTON
MADISON
DELAWARE
RANDOLPH
HENRY
WAYNE
HENDRICKS
HANCOCK
MORGAN
JOHNSON
SHELBY
RUSH
DECATUR
RIPLEY
CLAY
OWEN
GREENE
SULLIVAN
MONROE
JACKSON
LAWRENCE
ORANGE
GIBSON
FULTON
DEFIANCE
HENRY
WOOD
OTTAWA
SANDUSKY
SENECA
HURON
LORAIN
MEDINA
SUMMIT
PORTAGE
TRUMBULL
PUTNAM
HANCOCK
VAN WERT
ALLEN
HARDIN
WYANDOT
CRAWFORD
RICHLAND
ASHLAND
WAYNE
STARK
COLUMBIANA
MERCER
AUGLAIZE
LOGAN
MARION
MORROW
KNOX
HOLMES
TUSCARAWAS
CARROLL
HARRISON
SHELBY
DARKE
MIAMI
CHAMPAIGN
UNION
DELAWARE
LICKING
COSHOCTON
GUERNSEY
BELMONT
CLARK
MADISON
FRANKLIN
MUSKINGUM
NOBLE
MONROE
GREENE
FAYETTE
PAIRFIELD
PERRY
MORGAN
BUTLER
CLINTON
ROSS
HOCKING
ATHENS
WASHINGTON
HIGHLAND
PIKE
JACKSON
MEIGS
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
ERIE
CRAWFORD
WARREN
MCKEAN
POTTER
MERCER
VENANGO
CLARION
JEFFERSON
ELK
CLEARFIELD
CENTRE
BUTLER
ARMSTRONG
INDIANA
ALLEGHENY
WESTMORELAND
CAMBRIA
WASHINGTON
GREENE
FAYETTE
SOMERSET
BEDFORD
FULTON
CLINTON
HUNTINGDON
WETZEL
MARION
PRESTON
TYLER
RITCHIE
WIRT
CALHOUN
LEWIS
UPSHUR
RANDOLPH
TUCKER
GRANT
PENDLETON
MASON
JACKSON
ROANE
BRAXTON
WEBSTER
POCAHONTAS
KANAWHA
CLAY
NICHOLAS
FAYETTE
GREENBRIER
LOGAN
RALEIGH
WYOMING
SUMMERS
MCDOWELL
MERCER
MONROE
MASON
FLEMING
GREENUP
ROWAN
HARRISON
SCOTT
BOURBON
CLARK
SHELBY
UNION
HENDERSON
OHIO
GRAYSON
HOPKINS
HART
MARION
BOYLE
LINCOLN
ROCK CASTLE
ESTILL
FLOYD
PIKE
CASEY
PULASKI
CLAY
LESLIE
LETCHER
ADAIR
BARREN
GREEN
LOGAN
ALLEN
MONROE
WHITLEY
HARLAN
GRAVES
CALLOWAY
TRIGG

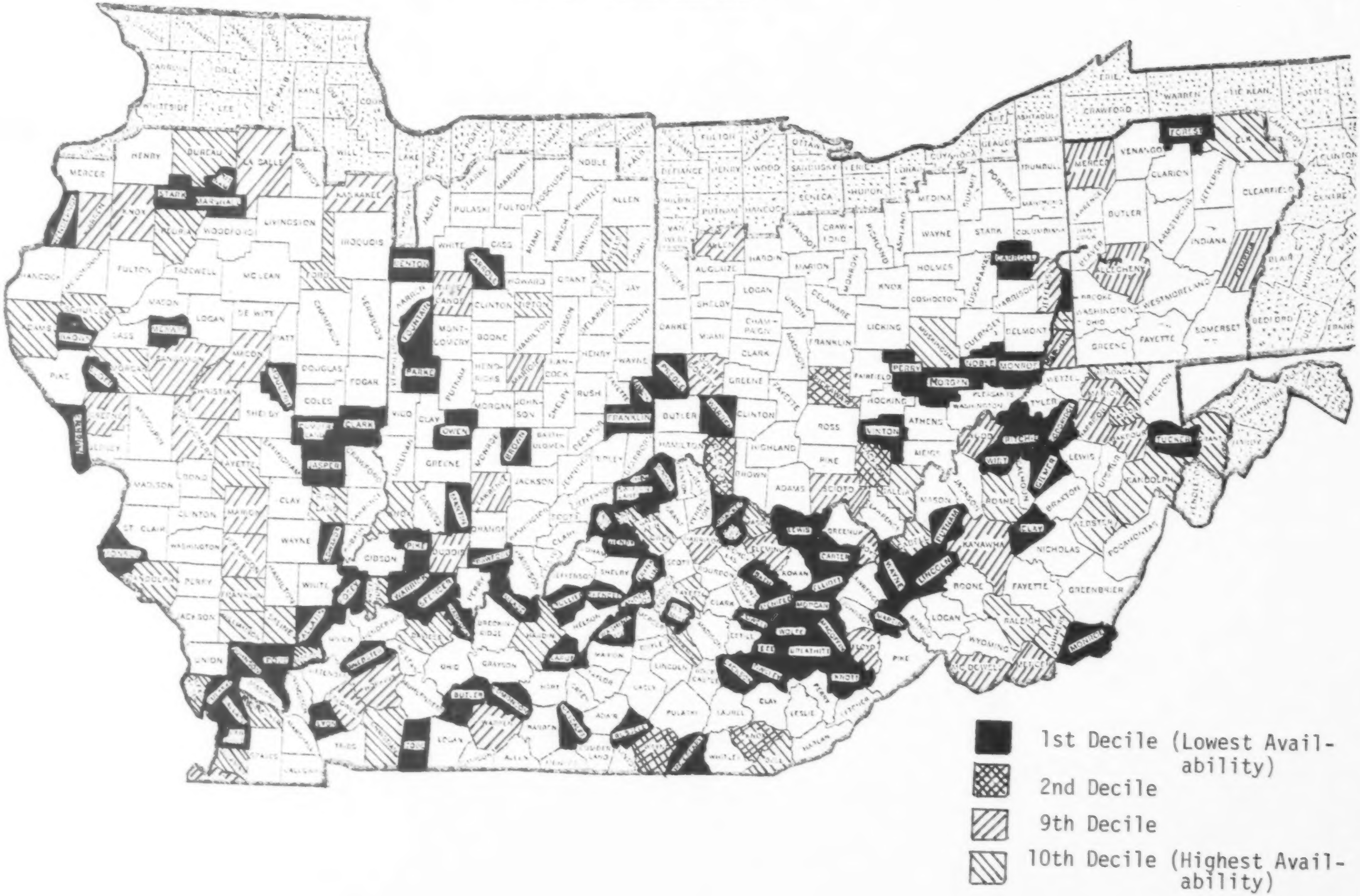

1st Decile (Lowest Availability)
2nd Decile
9th Decile
10th Decile (Highest Availability)

FIGURE 2.2.-6

Health Services Availability - Hospital Beds
Z Score Distribution

FIGURE 2.2.-7

Health Services Availability - Mean Z Scores

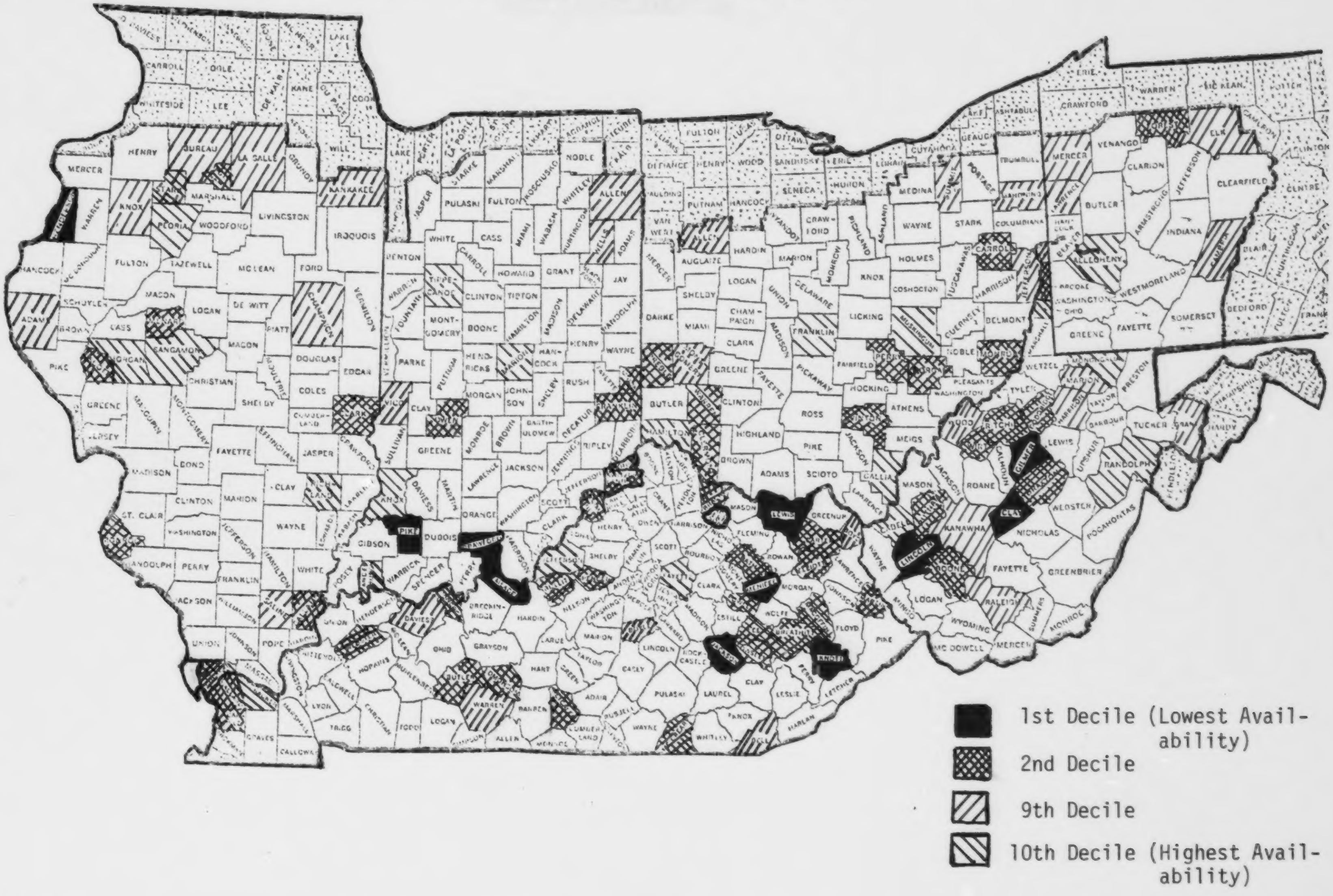

■ 1st Decile (Lowest Availability)
▩ 2nd Decile
▨ 9th Decile
▧ 10th Decile (Highest Availability)

TABLE 2.2.-1

Z-SCORE RANGES FOR EACH DECILE

Decile	Z score range	
1	-1.28 or less	(lowest health service) availability
2	-0.84 to -1.27	
3	-0.53 to -0.83	
4	-0.26 to -0.52	
5	0.00 to -0.25	
6	0.00 to 0.25	
7	0.25 to 0.52	
8	0.53 to 0.83	
9	0.84 to 1.27	
10	1.28 or greater	(highest health service availability

TABLE 2.2.-2

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Illinois	2	Bureau	36,700	0.23 (6)	0.96 (9)	1.13 (9)	2.02 (10)	1.70 (10)	1.21 (9)
		Fulton	42,400	0.07 (6)	-0.42 (4)	0.81 (8)	1.46 (10)	0.66 (8)	0.52 (7)
		Henderson	8,300	-0.83 (3)	-1.85 (1)	-1.55 (1)	-1.17 (2)	-1.29 (1)	-1.34 (1)
		Knox	61,300	1.20 (9)	0.33 (7)	0.47 (7)	1.73 (10)	0.99 (9)	0.94 (9)
		LaSalle	110,900	0.44 (7)	1.10 (9)	0.93 (9)	1.27 (9)	0.90 (9)	0.93 (9)
		Marshall	13,100	-0.04 (5)	1.85 (10)	-0.86 (2)	-1.17 (2)	-1.29 (1)	-0.30 (4)
		McDonough	39,500	0.22 (6)	0.45 (7)	-0.23 (5)	0.36 (7)	0.29 (7)	0.22 (6)
		Peoria	195,300	2.42 (10)	1.16 (9)	1.02 (9)	2.44 (10)	1.74 (10)	2.12 (10)
		Putnam	5,400	-0.16 (5)	-0.73 (3)	-1.14 (2)	-1.17 (2)	-1.29 (1)	-0.90 (2)
		Stark	7,200	-0.45 (4)	-1.01 (2)	-0.56 (3)	-1.17 (2)	-1.29 (1)	-0.90 (2)
		Tazewell	118,400	-0.07 (5)	0.06 (6)	-0.38 (4)	-0.36 (4)	-0.46 (4)	-0.24 (4)
		Warren	21,600	-0.35 (4)	0.68 (8)	0.03 (6)	0.73 (8)	1.00 (9)	0.41 (7)
		Woodford	29,100	-0.61 (3)	-0.39 (4)	-1.66 (1)	-0.64 (3)	-0.78 (3)	-0.82 (3)
	3	Adams	71,000	1.30 (10)	0.71 (8)	1.15 (9)	1.26 (9)	1.54 (10)	1.19 (9)
		Brown	5,500	-0.95 (2)	-0.75 (3)	1.13 (9)	-1.17 (2)	-1.29 (1)	-0.61 (3)
		Calhoun	5,500	-0.95 (2)	-0.75 (3)	2.28 (10)	-1.17 (2)	-1.29 (1)	-0.38 (4)
		Cass	14,100	-0.13 (5)	0.73 (8)	-0.07 (5)	0.28 (7)	-0.05 (5)	0.15 (5)
		Christian	36,200	0.07 (6)	-0.01 (5)	-0.04 (5)	0.20 (6)	1.15 (9)	0.27 (7)
		Greene	16,600	-0.57 (3)	-0.39 (4)	1.19 (9)	-0.17 (5)	0.95 (9)	0.19 (6)
		Hancock	22,400	-0.20 (5)	0.04 (6)	-0.62 (3)	0.27 (7)	0.35 (7)	-0.03 (5)
		Jersey	19,000	-0.44 (4)	0.06 (6)	0.01 (6)	-0.04 (4)	-0.33 (7)	-0.15 (5)
		Logan	31,100	0.58 (8)	0.49 (7)	0.33 (7)	0.78 (8)	0.53 (8)	0.54 (8)
		Macoupin	45,700	-0.27 (4)	0.14 (6)	0.17 (6)	-0.40 (4)	-0.25 (5)	-0.12 (5)
		Mason	17,600	-0.37 (4)	0.22 (6)	0.56 (8)	-0.34 (4)	-0.33 (4)	-0.05 (5)
		Menard	10,600	-0.54 (3)	-0.70 (3)	-0.52 (4)	-1.17 (2)	-1.29 (1)	-0.85 (2)
		Montgomery	30,500	-0.22 (5)	-0.46 (4)	-0.45 (4)	1.17 (9)	1.29 (9)	0.25 (6)
		Morgan	36,500	0.76 (8)	1.64 (10)	1.66 (10)	1.43 (10)	1.53 (10)	1.40 (10)
		Pike	19,200	-0.23 (5)	0.36 (7)	-0.67 (8)	0.30 (7)	0.28 (7)	0.01 (6)
		Sangamon	161,200	2.42 (10)	1.02 (9)	1.09 (9)	2.42 (10)	1.24 (9)	1.64 (10)
		Schuyler	7,900	-0.53 (3)	-0.31 (4)	0.09 (6)	1.67 (10)	2.62 (10)	0.71 (8)
		Scott	6,100	-0.64 (3)	-0.86 (2)	-1.28 (1)	-1.17 (2)	-1.29 (1)	-1.05 (2)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Illinois (Cont)	4	Champaign	163,100	1.36 (10)	0.72 (8)	0.63 (8)	2.11 (10)	0.34 (7)	1.03 (9)
		Clark	16,100	-0.55 (3)	-1.10 (2)	-0.74 (3)	-1.17 (2)	-1.29 (1)	-0.97 (2)
		Coles	47,100	0.11 (6)	0.72 (8)	0.23 (6)	0.55 (8)	-0.06 (5)	0.31 (7)
		Cumberland	10,300	-0.51 (4)	0.50 (7)	0.14 (6)	-1.17 (2)	-1.29 (1)	-0.47 (4)
		Dewitt	16,800	-0.33 (4)	-0.77 (3)	-0.81 (3)	-0.24 (5)	-0.37 (4)	-0.50 (4)
		Douglas	19,000	-0.33 (4)	1.66 (10)	0.01 (6)	-0.20 (5)	-0.46 (4)	-0.14 (5)
		Edgar	21,300	0.16 (6)	0.71 (8)	0.65 (8)	0.20 (6)	0.32 (7)	0.41 (7)
		Ford	15,000	0.08 (6)	0.57 (8)	0.21 (6)	0.72 (8)	1.61 (10)	0.64 (8)
		Iroquois	33,300	0.00 (6)	0.52 (7)	0.79 (8)	0.21 (6)	0.57 (8)	0.10 (6)
		Livingston	40,800	-0.04 (5)	-0.21 (5)	-1.07 (2)	0.50 (7)	0.49 (7)	-0.07 (5)
		Macon	125,000	0.96 (9)	0.47 (7)	0.06 (6)	0.53 (8)	1.06 (9)	0.62 (8)
		McLean	104,600	0.37 (7)	0.85 (9)	0.28 (7)	0.90 (9)	0.76 (8)	0.63 (8)
		Moultrie	13,000	-0.03 (5)	0.02 (6)	1.09 (9)	-1.17 (2)	-1.29 (1)	-0.28 (4)
		Piatt	15,600	-0.25 (5)	-0.68 (3)	0.12 (6)	-0.42 (4)	-0.53 (3)	-0.35 (4)
		Shelby	22,900	-0.50 (4)	0.00 (6)	-1.76 (1)	-0.19 (5)	-0.31 (4)	-0.55 (3)
		Vermillion	98,200	0.66 (8)	0.56 (8)	0.45 (7)	1.11 (9)	0.43 (7)	0.64 (8)
	5	Alexander	11,500	0.46 (6)	-0.27 (4)	-1.21 (2)	3.16 (10)	2.22 (10)	0.81 (8)
		Bond	14,900	-0.05 (5)	-0.63 (3)	-0.62 (3)	-0.25 (5)	-0.40 (7)	-0.23 (5)
		Clay	14,900	-0.34 (4)	-0.22 (5)	-1.46 (1)	-0.39 (4)	-0.16 (5)	-0.51 (4)
		Crawford	19,500	0.30 (7)	0.95 (9)	-0.37 (4)	-0.07 (5)	0.58 (8)	0.28 (7)
		Edwards	7,500	-0.21 (5)	1.38 (10)	0.21 (6)	-1.17 (2)	-1.29 (1)	-0.21 (5)
		Effingham	26,600	0.42 (7)	0.88 (9)	-0.41 (4)	0.77 (8)	0.56 (8)	0.44 (7)
		Fayette	20,700	-0.52 (4)	-0.39 (4)	-0.18 (5)	0.43 (7)	1.95 (10)	0.26 (7)
		Franklin	40,900	-0.25 (5)	-0.22 (5)	-0.15 (5)	0.09 (6)	1.33 (10)	0.16 (6)
		Gallatin	7,300	-0.47 (4)	-1.02 (2)	-0.58 (3)	-1.17 (2)	-1.29 (1)	-0.91 (2)
		Hamilton	8,900	-0.14 (5)	-0.49 (4)	-0.89 (2)	-0.40 (4)	0.68 (8)	-0.25 (5)
		Hardin	5,000	-0.06 (5)	-0.64 (3)	1.47 (10)	0.20 (5)	1.87 (10)	0.57 (8)
		Jackson	52,500	1.26 (9)	1.15 (9)	0.33 (7)	0.54 (8)	-0.07 (5)	0.64 (8)
		Jasper	10,800	-0.75 (3)	-0.17 (5)	-0.56 (3)	-1.17 (2)	-1.29 (1)	-0.79 (3)
		Jefferson	33,300	0.47 (7)	0.17 (6)	0.94 (9)	0.55 (8)	0.84 (9)	0.59 (8)
		Johnson	8,700	-1.10 (2)	-0.46 (4)	-0.13 (5)	-1.17 (2)	-1.29 (1)	-0.83 (3)
		Lawrence	17,900	-0.39 (4)	0.18 (6)	-0.55 (3)	0.08 (6)	-0.02 (5)	-0.14 (5)
		Marion	39,800	0.64 (8)	1.20 (9)	0.38 (7)	0.55 (8)	0.97 (9)	0.75 (8)
		Massac	13,600	-0.40 (4)	-0.07 (5)	-0.92 (2)	-0.45 (4)	0.49 (7)	-0.27 (4)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Illinois (Cont)	5 (Cont)	Perry	20,100	0.25 (6)	-0.34 (4)	0.83 (8)	0.19 (6)	0.72 (8)	0.33 (7)
		Pope	4,300	-0.85 (2)	-0.44 (4)	0.62 (8)	-1.17 (2)	-1.29 (1)	-0.63 (3)
		Pulaski	8,800	-0.86 (2)	-1.85 (1)	-0.16 (5)	-1.17 (2)	-1.29 (1)	-1.07 (2)
		Randolph	32,000	0.19 (6)	-0.14 (5)	-0.34 (4)	0.84 (9)	1.39 (1)	0.39 (7)
		Richland	16,900	1.81 (10)	1.02 (9)	1.05 (9)	1.78 (10)	1.82 (10)	1.50 (10)
		Saline	26,300	0.60 (8)	0.92 (9)	1.05 (9)	0.83 (8)	1.50 (10)	0.98 (9)
		Union	16,000	0.92 (9)	0.80 (8)	-0.34 (4)	-0.56 (3)	-0.24 (5)	0.12 (6)
		Wabash	13,600	-0.40 (4)	0.38 (7)	0.01 (6)	0.19 (6)	0.75 (8)	0.19 (6)
		Washington	14,500	-0.75 (3)	-0.18 (5)	0.30 (7)	-0.30 (4)	0.45 (4)	-0.10 (5)
		Wayne	17,200	-0.35 (4)	0.27 (7)	0.84 (9)	-0.15 (5)	0.65 (8)	-0.09 (5)
		White	16,400	1.39 (10)	0.00 (6)	0.77 (8)	-0.46 (4)	-0.07 (5)	0.32 (7)
		Williamson	51,800	0.06 (6)	0.02 (6)	1.22 (9)	0.70 (8)	1.32 (10)	0.66 (8)
	9	Grundy	27,500	-0.33 (4)	0.80 (8)	0.44 (7)	0.07 (6)	-0.33 (4)	0.13 (6)
		Kankakee	96,000	1.21 (9)	0.87 (9)	1.11 (9)	1.14 (9)	0.85 (9)	1.03 (9)
	10	Henry	54,300	-0.16 (5)	0.16 (6)	0.33 (7)	0.30 (7)	0.09 (6)	0.01 (6)
		Mercer	17,100	-0.59 (3)	-1.14 (2)	-0.47 (4)	0.26 (7)	0.00 (6)	-0.39 (4)
	11	Clinton	29,600	-0.41 (4)	-0.01 (5)	-0.60 (3)	-0.18 (5)	-0.06 (5)	-0.25 (5)
		Madison	250,900	0.11 (6)	0.75 (8)	0.50 (7)	0.63 (8)	0.46 (7)	0.49 (7)
		Monroe	18,900	-0.44 (4)	-0.25 (5)	-1.31 (1)	-1.17 (2)	-1.29 (1)	-0.89 (2)
		St. Clair	285,100	0.17 (6)	-0.05 (5)	0.86 (9)	0.99 (9)	0.79 (8)	0.55 (8)
Indiana	1	Adams	27,400	-0.41 (4)	0.36 (7)	-0.24 (5)	-0.03 (5)	-0.36 (4)	-0.13 (5)
		Allen	280,600	1.17 (9)	0.92 (9)	1.10 (9)	1.50 (10)	0.83 (8)	1.10 (9)
		Cass	40,700	0.49 (7)	-0.21 (5)	-0.60 (3)	0.63 (8)	0.61 (8)	0.18 (6)
		Fulton	17,700	-0.14 (5)	0.55 (8)	1.25 (9)	-0.23 (5)	-0.34 (4)	0.22 (6)
		Hungtington	35,800	-0.21 (5)	0.18 (6)	0.33 (7)	-0.33 (4)	-0.53 (3)	-0.11 (5)
		Jasper	22,700	-0.50 (4)	-0.25 (5)	1.02 (9)	-0.27 (4)	-0.39 (4)	-0.08 (5)
		Kosciusko	52,200	-0.16 (5)	0.01 (6)	0.59 (8)	-0.46 (4)	-0.78 (3)	-0.16 (5)
		Marshall	38,100	-0.17 (5)	0.54 (8)	1.17 (9)	0.01 (6)	-0.39 (4)	0.23 (6)
		Miami	40,300	-0.39 (4)	-0.04 (5)	-0.74 (3)	0.06 (6)	-0.27 (4)	-0.27 (4)
		Noble	32,900	-0.37 (4)	0.36 (7)	0.37 (7)	-0.19 (5)	-0.52 (4)	-0.07 (5)
		Pulaski	12,800	-0.51 (4)	0.04 (6)	0.65 (8)	0.20 (6)	0.41 (7)	0.16 (6)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Indiana (Cont.)	1 (Cont)	Starke	20,800	-0.52 (4)	-0.97 (2)	-0.79 (3)	-0.37 (4)	0.01 (6)	-0.53 (3)
		Wabash	35,400	0.28 (7)	0.38 (7)	0.72 (8)	0.54 (8)	0.19 (6)	0.42 (7)
		Wells	25,000	2.32 (10)	-0.15 (5)	-0.29 (4)	2.07 (10)	2.03 (10)	1.20 (9)
		Whitley	24,800	-0.57 (3)	0.59 (8)	-0.27 (4)	0.05 (6)	-0.10 (5)	-0.06 (5)
	2	Benton	11,200	-0.20 (5)	0.32 (7)	1.07 (9)	-1.17 (2)	-1.29 (1)	-0.26 (4)
		Blackford	16,000	-0.01 (5)	0.80 (8)	0.06 (6)	0.05 (6)	-0.26 (4)	0.13 (6)
		Boone	32,000	0.26 (7)	0.61 (8)	2.22 (10)	-0.13 (5)	-0.38 (4)	-0.52 (4)
		Carroll	18,200	-0.17 (5)	-0.18 (5)	-0.58 (3)	-1.17 (2)	-1.29 (1)	-0.68 (3)
		Clinton	30,800	-0.51 (4)	0.12 (6)	0.15 (6)	-0.28 (4)	-0.31 (4)	-0.17 (5)
		Delaware	128,900	1.09 (9)	0.15 (6)	-0.33 (4)	0.01 (6)	0.30 (7)	0.24 (6)
		Fayette	27,400	-0.25 (5)	-0.08 (5)	0.22 (6)	0.18 (6)	0.14 (6)	0.04 (6)
		Fountain	18,600	-0.31 (4)	1.08 (9)	1.08 (9)	-1.17 (2)	-1.29 (1)	-0.12 (5)
		Franklin	17,600	-0.86 (2)	-1.16 (2)	-1.23 (2)	-1.17 (2)	-1.29 (1)	-1.14 (2)
		Grant	84,400	0.55 (8)	0.09 (6)	0.75 (8)	-0.14 (5)	-0.08 (5)	0.24 (6)
		Hamilton	65,100	0.79 (8)	0.39 (7)	0.31 (7)	-0.17 (5)	-0.45 (4)	0.17 (6)
		Hancock	40,300	-0.13 (5)	-0.04 (5)	1.45 (10)	0.09 (6)	-0.27 (4)	0.22 (6)
		Hendricks	59,900	-0.17 (5)	-0.23 (5)	0.32 (7)	-0.10 (5)	-0.55 (3)	-0.14 (5)
		Henry	53,200	0.14 (6)	-0.03 (5)	-0.53 (3)	-0.46 (4)	-0.10 (5)	-0.19 (5)
		Howard	88,300	0.28 (7)	0.76 (8)	0.90 (9)	0.94 (9)	0.46 (7)	0.67 (8)
		Jay	24,100	-0.63 (3)	-0.34 (4)	-0.05 (5)	-0.08 (5)	0.34 (7)	-0.13 (5)
		Johnson	60,800	0.54 (8)	0.39 (7)	0.57 (8)	-0.28 (4)	-0.34 (4)	0.18 (6)
		Madison	138,300	0.22 (6)	0.54 (8)	0.18 (6)	0.51 (8)	0.29 (7)	0.35 (7)
		Marion	792,300	3.38 (10)	2.62 (10)	4.79 (10)	1.94 (10)	0.98 (9)	2.74 (10)
		Montgomery	34,400	0.15 (6)	0.44 (7)	-0.11 (5)	0.11 (6)	0.21 (6)	0.16 (6)
		Morgan	47,300	-0.22 (5)	-0.31 (4)	-0.71 (3)	-0.39 (4)	-0.39 (4)	-0.40 (4)
		Randolph	29,500	-0.11 (5)	0.82 (3)	-0.60 (3)	0.05 (6)	0.15 (6)	0.06 (6)
		Rush	20,900	-0.22 (5)	-0.69 (3)	-0.50 (4)	-0.05 (5)	0.04 (6)	-0.28 (4)
		Shelby	39,100	-0.25 (5)	-0.45 (4)	-0.37 (4)	-0.20 (5)	-0.42 (4)	-0.34 (4)
		Tippecanoe	109,400	1.68 (10)	0.69 (8)	4.83 (10)	1.54 (10)	1.02 (9)	1.95 (10)
		Tipton	16,000	0.12 (6)	0.42 (7)	0.06 (6)	1.52 (10)	1.69 (10)	0.76 (8)
		Union	6,700	-1.02 (2)	-0.94 (2)	-1.37 (1)	-1.17 (2)	-1.29 (1)	-1.16 (2)
		Warren	8,500	-0.59 (3)	-1.85 (1)	-1.57 (1)	0.21 (6)	0.15 (6)	-0.73 (3)
		Wayne	79,200	0.89 (9)	0.83 (3)	0.56 (8)	0.15 (6)	0.49 (7)	0.58 (8)
		White	21,900	-0.27 (4)	1.47 (10)	0.86 (9)	-0.82 (3)	-0.52 (4)	0.14 (6)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Indiana (Cont.)	3	Bartholomew	59,100	1.18 (9)	0.71 (8)	0.25 (6)	0.88 (9)	0.19 (6)	0.64 (8)
		Brown	9,700	-0.46 (4)	-1.22 (2)	0.94 (9)	-1.17 (2)	-1.29 (1)	-0.64 (3)
		Clark	80,900	0.50 (7)	-0.20 (5)	0.34 (7)	0.28 (7)	0.28 (4)	0.13 (6)
		Clay	24,400	-0.38 (4)	0.14 (6)	0.02 (6)	0.31 (7)	0.26 (7)	0.07 (6)
		Crawford	8,700	-1.10 (2)	-1.15 (2)	-2.31 (1)	-1.17 (2)	-1.29 (1)	-1.40 (1)
		Daviess	26,700	-0.22 (5)	0.19 (6)	0.29 (7)	1.35 (10)	0.48 (7)	0.42 (7)
		Dearborn	30,800	-0.51 (4)	-0.67 (3)	0.35 (7)	0.10 (6)	0.00 (6)	-0.15 (5)
		Decatur	23,100	-0.42 (4)	-0.01 (5)	2.33 (10)	0.22 (6)	-0.02 (5)	0.42 (7)
		Dubois	31,900	0.53 (8)	-0.52 (4)	0.46 (7)	0.85 (9)	1.15 (9)	0.49 (7)
		Floyd	57,700	0.54 (8)	1.09 (9)	0.53 (8)	0.54 (8)	0.29 (7)	0.60 (8)
		Gibson	31,400	-0.53 (3)	0.66 (8)	0.10 (6)	0.20 (6)	0.42 (7)	0.17 (6)
		Greene	28,100	-0.28 (4)	0.74 (8)	0.16 (6)	-0.27 (4)	-0.34 (4)	0.00 (6)
		Hanison	23,100	-0.60 (3)	-0.01 (5)	-1.49 (1)	-0.33 (4)	-0.30 (4)	-0.55 (3)
		Jackson	34,200	-0.34 (4)	0.63 (8)	1.75 (10)	0.26 (7)	0.21 (6)	0.50 (7)
		Jefferson	27,700	1.12 (9)	0.12 (6)	1.10 (9)	0.06 (6)	0.36 (7)	0.55 (8)
		Jennings	20,600	-0.51 (4)	-0.67 (3)	-1.39 (1)	-0.65 (3)	-0.47 (4)	-0.74 (3)
		Knox	40,900	0.95 (9)	1.41 (10)	2.16 (10)	1.79 (10)	1.42 (10)	1.55 (10)
		Lawrence	40,700	0.91 (9)	-0.51 (4)	0.48 (7)	0.48 (7)	0.84 (9)	0.44 (7)
		Martin	11,000	-0.76 (3)	0.91 (9)	-1.16 (2)	-1.17 (2)	-1.29 (1)	-0.70 (3)
		Monroe	89,100	1.27 (9)	1.14 (9)	0.31 (7)	-0.16 (5)	-0.11 (5)	0.49 (7)
		Ohio	4,600	-0.88 (2)	-0.53 (3)	-0.94 (2)	-1.17 (2)	-1.29 (1)	-0.96 (2)
		Orange	17,400	-0.12 (5)	0.24 (6)	0.59 (8)	-0.50 (4)	0.04 (6)	0.05 (6)
		Owen	13,100	-0.85 (2)	-1.39 (1)	-0.38 (4)	-1.17 (2)	-1.29 (1)	-1.02 (2)
		Parke	15,600	-0.52 (4)	0.09 (6)	-1.10 (2)	-1.17 (2)	-1.29 (1)	-0.80 (3)
		Perry	19,100	-0.45 (4)	0.69 (8)	0.00 (6)	-0.05 (5)	-0.28 (4)	-0.02 (5)
		Pike	12,100	-0.99 (2)	-1.35 (1)	-1.79 (1)	-1.17 (2)	-1.29 (1)	-1.32 (1)
		Posey	22,900	-0.78 (3)	-0.53 (3)	-0.38 (4)	-1.17 (2)	-1.29 (1)	-0.83 (3)
		Putnum	27,600	-0.26 (4)	0.35 (7)	0.20 (6)	-0.08 (5)	-0.26 (4)	-0.01 (5)
		Ripley	22,300	-0.48 (4)	0.05 (6)	-0.33 (4)	0.01 (6)	0.60 (8)	-0.03 (5)
		Scott	18,600	-0.20 (5)	-0.22 (5)	-0.27 (4)	-0.28 (4)	-0.12 (5)	-0.22 (5)
		Spencer	17,700	-0.98 (2)	-0.14 (5)	-0.53 (3)	-1.17 (2)	-1.29 (1)	-0.82 (3)
		Sullivan	19,400	-0.24 (5)	0.96 (9)	0.62 (8)	0.44 (7)	0.52 (7)	0.46 (7)
		Switzerland	6,600	-1.02	-0.01 (5)	-1.35 (1)	-1.17 (2)	-1.29 (1)	-0.97 (2)
		Vanderburg	168,600	2.24 (10)	1.77 (10)	2.53 (10)	2.09 (10)	1.85 (10)	2.10 (10)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Indiana (Cont.)	3 (Cont)	Vermillion	17,100	-0.47 (4)	-0.08 (5)	-0.47 (4)	-0.66 (3)	-0.22 (5)	-0.38 (4)
		Vigo	114,400	1.04 (9)	1.32 (10)	0.38 (7)	1.14 (9)	0.61 (8)	0.90 (9)
		Warrick	33,300	-0.77 (3)	-0.57 (3)	0.34 (7)	-1.17 (2)	-1.29 (1)	-0.69 (3)
		Washington	19,800	-0.59 (3)	-0.62 (3)	-1.03 (2)	-0.19 (5)	-0.17 (5)	-0.52 (4)
Ohio	1	Adams	27,000	-0.50 (4)	-1.31 (1)	0.19 (6)	-0.18 (5)	0.13 (6)	-0.33 (4)
		Boone*	36,200	-0.22 (5)	-0.01 (5)	0.13 (6)	-1.17 (2)	-1.29 (1)	-0.51 (4)
		Brown	29,500	-0.55 (3)	-0.62 (3)	0.04 (6)	0.42 (7)	0.29 (7)	-0.08 (5)
		Butler	226,300	0.46 (7)	0.28 (7)	-0.15 (5)	0.66 (8)	0.29 (7)	0.31 (7)
		Campbell*	85,000	0.29 (7)	-0.28 (4)	1.55 (10)	0.13 (6)	-0.40 (4)	0.26 (7)
		Clermont	85,300	-0.79 (3)	-0.69 (3)	-1.10 (2)	-0.91 (2)	-1.08 (2)	-0.92 (2)
		Clinton	32,300	-0.09 (5)	0.03 (6)	0.81 (8)	0.22 (6)	0.44 (7)	0.28 (7)
		Hamilton	923,900	3.67 (10)	1.24 (9)	2.35 (10)	1.28 (10)	0.63 (8)	1.83 (10)
		Highland	31,000	0.03 (6)	0.30 (7)	-0.68 (3)	-0.57 (3)	0.32 (7)	-0.12 (5)
		Kenton*	120,100	0.83 (8)	-0.13 (5)	1.56 (10)	0.70 (8)	0.38 (4)	0.67 (8)
		Warren	86,900	-0.83 (3)	-0.45 (4)	-0.64 (3)	-1.17 (2)	-1.29 (1)	-0.88 (2)
	2	Champaign	32,100	-0.21 (5)	0.04 (6)	-0.15 (5)	-0.17 (5)	-0.35 (4)	-0.17 (5)
		Clark	156,800	0.36 (7)	0.57 (8)	-0.04 (5)	0.49 (7)	0.10 (6)	0.30 (7)
		Darke	53,500	-0.43 (4)	-0.72 (3)	-0.42 (4)	-0.37 (4)	-0.59 (3)	-0.50 (4)
		Greene	124,900	-0.04 (5)	-0.41 (4)	-0.56 (3)	-0.71 (3)	-0.81 (3)	-0.51 (4)
		Miami	87,200	0.20 (6)	0.38 (7)	0.58 (8)	1.06 (9)	0.70 (8)	0.58 (8)
		Montgomery	605,900	1.61 (10)	1.31 (10)	0.90 (9)	1.44 (10)	0.97 (9)	1.24 (9)
		Preble	35,900	-0.87 (2)	-0.50 (4)	-1.08 (2)	-1.17 (2)	-1.29 (1)	-0.98 (2)
		Shelby	40,000	-0.28 (4)	-1.70 (1)	-0.42 (4)	-0.07 (5)	-0.55 (3)	-0.60 (3)
	3	Allen	110,800	1.19 (9)	0.77 (8)	0.94 (9)	2.14 (10)	1.27 (9)	1.26 (9)
		Auglaize	40,700	-0.56 (3)	0.09 (6)	0.32 (7)	-0.09 (5)	-0.26 (4)	-0.10 (5)
		Hardin	31,700	-0.40 (4)	-0.51 (4)	2.86 (10)	0.37 (7)	0.07 (6)	0.48 (7)
		Logan	36,600	0.17 (6)	0.14 (6)	0.45 (7)	0.06 (6)	-0.26 (4)	0.11 (6)
		Mercer	37,400	-0.49 (4)	0.42 (7)	-0.79 (3)	-0.10 (5)	-0.30 (4)	-0.25 (5)
	5	Delaware	50,400	-0.28 (4)	0.20 (6)	-0.43 (4)	-0.46 (4)	-0.39 (4)	-0.27 (4)
		Fairfield	82,500	-0.23 (5)	0.57 (8)	-0.25 (5)	-0.36 (4)	-0.78 (3)	-0.21 (5)
		Fayette	26,400	-0.29 (4)	0.22 (6)	-0.40 (4)	-0.25 (5)	-0.13 (5)	-0.17 (5)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Ohio (Cont.)	5 (Cont)	Franklin	833,300	2.68 (10)	2.48 (10)	2.09 (10)	1.12 (9)	0.40 (7)	1.75 (10)
		Knox	43,900	0.55 (8)	0.64 (8)	0.85 (9)	0.45 (7)	0.36 (7)	0.57 (8)
		Licking	108,000	0.12 (6)	0.15 (6)	0.45 (7)	-0.15 (5)	-0.28 (4)	0.06 (6)
		Madison	31,000	-0.31 (4)	-0.09 (5)	0.54 (8)	-0.07 (5)	-0.20 (5)	-0.03 (5)
		Marion	66,900	1.46 (10)	0.23 (6)	0.14 (6)	0.65 (8)	0.55 (8)	0.61 (8)
		Morrow	23,900	-0.81 (3)	4.49 (10)	-0.73 (3)	-0.40 (4)	0.00 (6)	0.51 (7)
		Pickaway	44,000	-0.08 (5)	-0.47 (4)	-0.59 (3)	-0.86 (2)	-0.84 (2)	-0.57 (3)
		Pike	20,400	0.02 (6)	-1.25 (2)	-0.15 (5)	-0.55 (3)	-0.17 (5)	-0.42 (4)
		Ross	60,700	0.34 (7)	0.95 (9)	0.29 (7)	0.16 (6)	0.04 (6)	0.36 (7)
		Scioto	78,800	0.58 (8)	0.15 (6)	0.41 (7)	0.73 (8)	0.89 (9)	0.55 (8)
		Union	25,700	0.07 (6)	-1.38 (1)	-0.35 (4)	0.01 (6)	0.03 (6)	-0.32 (4)
		Wyandot	22,600	-0.59 (3)	2.17 (10)	-0.08 (5)	0.04 (6)	-0.48 (4)	0.21 (6)
	6	Athens	53,200	0.34 (7)	-0.03 (5)	-0.29 (4)	-0.20 (5)	-0.02 (5)	-0.04 (5)
		Belmont	82,500	0.11 (6)	0.28 (7)	-0.02 (5)	0.65 (8)	0.35 (7)	0.28 (7)
		Coshocton	34,600	-0.29 (4)	0.08 (6)	0.06 (6)	0.49 (7)	0.50 (7)	0.17 (6)
		Gallia	27,500	1.91 (10)	0.57 (8)	-0.25 (5)	2.13 (10)	2.08 (10)	1.29 (10)
		Guernsey	39,600	0.17 (6)	0.45 (7)	-1.03 (2)	0.48 (7)	0.04 (6)	0.02 (6)
		Harrison	17,400	-0.12 (5)	-1.15 (2)	0.23 (6)	-0.50 (4)	-0.26 (4)	-0.36 (4)
		Hocking	21,600	-0.26 (4)	0.12 (6)	-0.27 (4)	-0.31 (4)	0.20 (6)	-0.10 (5)
		Jackson	28,700	-0.52 (4)	1.54 (10)	-0.55 (3)	-0.73 (3)	-0.96 (2)	-0.25 (5)
		Jefferson	96,200	0.47 (8)	0.23 (6)	0.25 (6)	2.57 (10)	0.97 (9)	0.90 (9)
		Lawrence	60,500	-0.46 (4)	-0.35 (4)	-0.75 (3)	-0.20 (5)	-0.48 (4)	-0.45 (4)
		Meigs	21,500	-1.04 (2)	-0.44 (4)	0.04 (6)	-0.58 (3)	0.15 (6)	-0.38 (4)
		Monroe	15,800	-0.94 (2)	-1.46 (1)	-0.71 (3)	-1.17 (2)	-1.29 (1)	-1.12 (2)
		Morgan	13,400	-1.02 (2)	-0.94 (2)	-0.43 (4)	-1.17 (2)	-1.29 (1)	-0.97 (2)
		Muskingum	80,100	0.73 (8)	0.57 (8)	2.10 (10)	1.49 (10)	2.01 (10)	1.38 (10)
		Noble	10,800	-0.75 (3)	0.40 (7)	-0.56 (3)	-1.17 (2)	-1.29 (1)	-0.67 (3)
		Perry	30,000	-0.70 (3)	-0.64 (3)	-1.05 (2)	-1.17 (2)	-1.29 (1)	-0.97 (2)
		Vinton	10,500	-1.34 (1)	-0.69 (3)	-1.11 (2)	-1.17 (2)	-1.29 (1)	-1.12 (2)
		Washington	59,200	-0.01 (5)	0.30 (7)	-0.39 (4)	0.41 (7)	0.40 (7)	0.14 (6)
	7	Ashland	42,200	-0.04 (5)	0.48 (7)	-0.17 (5)	0.31 (7)	-0.28 (4)	0.06 (6)
		Carroll	24,600	-0.91 (2)	-0.62 (3)	-1.03 (2)	-1.17 (2)	-1.29 (1)	-1.00 (2)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Ohio (Cont.)	7 (Cont)	Crawford	50,200	0.40 (7)	0.20 (6)	0.83 (8)	0.89 (9)	0.78 (8)	0.62 (8)
		Holmes	24,600	-0.56 (3)	-0.86 (2)	-1.28 (1)	-0.46 (4)	-0.51 (4)	-0.73 (3)
		Richland	129,600	0.66 (8)	0.97 (9)	0.24 (6)	0.81 (8)	0.52 (7)	0.64 (8)
		Stark	372,400	0.92 (9)	1.02 (9)	0.03 (6)	1.49 (10)	0.41 (7)	0.77 (8)
		Tuscarawas	79,300	0.19 (6)	0.14 (6)	0.16 (6)	0.58 (8)	-0.01 (5)	0.21 (6)
		Wayne	91,400	0.03 (6)	0.27 (7)	0.04 (6)	0.05 (6)	-0.18 (5)	0.04 (6)
	8	Portage	125,700	-0.04 (5)	-0.32 (4)	-0.24 (5)	-0.41 (4)	-0.66 (3)	-0.34 (4)
		Summit	553,600	2.15 (10)	1.38 (10)	0.33 (7)	0.77 (8)	0.17 (6)	0.96 (9)
	9	Medina	94,600	0.03 (6)	0.39 (7)	-0.18 (5)	0.21 (6)	-0.15 (5)	0.06 (6)
	10	Columbiana	108,300	-0.03 (5)	-0.04 (5)	-0.08 (5)	1.00 (9)	0.21 (6)	0.21 (6)
		Mahoning	303,700	1.97 (10)	1.06 (9)	0.49 (7)	1.58 (10)	0.66 (8)	1.15 (9)
		Trumball	232,300	0.37 (7)	0.53 (8)	0.56 (8)	0.93 (9)	0.18 (6)	0.51 (7)
Kentucky	1	Allen	12,400	-0.55 (3)	-0.04 (5)	0.51 (7)	-0.59 (3)	0.10 (6)	-0.11 (5)
		Ballard	8,300	-0.31 (4)	-1.85 (1)	-1.55 (1)	-1.17 (2)	-1.29 (1)	-1.23 (2)
		Barren	30,500	0.20 (6)	-0.46 (4)	2.24 (10)	-0.31 (7)	0.58 (8)	0.45 (7)
		Breckinridge	15,400	-0.51 (4)	-1.06 (2)	0.97 (9)	-0.67 (3)	-0.27 (4)	-0.31 (4)
		Bullitt	31,600	-1.00 (2)	-1.27 (2)	-1.31 (1)	-1.17 (2)	-1.29 (1)	-1.21 (2)
		Butler	10,200	-0.92 (2)	-1.85 (1)	-0.45 (4)	-1.17 (2)	-1.29 (1)	-1.14 (2)
		Caldwell	13,000	-0.19 (5)	0.02 (6)	1.57 (10)	-0.12 (5)	1.00 (9)	0.46 (7)
		Calloway	28,600	0.15 (6)	0.69 (8)	0.56 (8)	0.09 (6)	0.76 (8)	0.45 (7)
		Carlisle	5,400	-1.34 (1)	-0.73 (3)	0.03 (6)	-1.17 (2)	-1.29 (1)	-0.90 (2)
		Christian	68,000	0.50 (7)	-0.16 (5)	0.37 (7)	1.55 (10)	1.98 (10)	0.75 (8)
		Crittenden	9,400	-0.89 (2)	-0.56 (3)	1.71 (10)	0.07 (6)	0.09 (6)	0.09 (6)
		Daviess	81,000	0.63 (8)	0.69 (8)	1.19 (9)	1.87 (10)	1.74 (10)	1.23 (9)
		Edmonson	9,100	-0.87 (2)	-1.85 (1)	0.46 (7)	-1.17 (2)	-1.29 (1)	-0.94 (2)
		Fulton	9,600	0.43 (7)	0.68 (8)	2.29 (10)	-0.56 (3)	1.19 (9)	0.81 (8)
		Graves	31,800	0.00 (6)	0.06 (6)	1.26 (9)	-0.22 (5)	0.09 (6)	0.24 (6)
		Grayson	17,600	-0.49 (4)	-0.82 (3)	0.56 (8)	-0.40 (4)	-0.49 (4)	-0.33 (4)
		Hancock	7,300	-1.05 (2)	-1.02 (2)	-0.58	-1.17 (2)	-1.29 (1)	-1.02 (2)
		Hardin	73,600	0.34 (7)	-0.53 (3)	-0.25 (5)	1.74 (10)	2.22 (10)	0.70 (8)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Kentucky (Cont.)	1 (Cont)	Hart	14,900	-0.63 (3)	-0.63 (3)	-0.19 (5)	-0.65 (3)	-0.49 (4)	-0.52 (4)
		Henderson	36,800	0.51 (7)	0.13 (6)	0.43 (7)	0.53 (8)	0.53 (8)	0.43 (7)
		Henry	11,400	-0.59 (3)	-0.25 (5)	-0.10 (5)	-1.17 (2)	-1.29 (1)	-0.68 (3)
		Hickman	6,800	-0.71 (3)	-0.07 (5)	-0.45 (4)	1.42 (10)	1.34 (10)	0.30 (7)
		Hopkins	41,500	1.84 (10)	-0.24 (5)	1.18 (9)	0.15 (6)	1.01 (9)	0.79 (8)
		Jefferson	695,300	2.73 (10)	1.34 (10)	1.02 (9)	1.32 (10)	0.75	1.43 (10)
		Larue	11,300	-0.40 (4)	-0.78 (3)	-0.08 (5)	-1.17 (2)	-1.29 (1)	-0.74 (3)
		Livingston	8,400	-0.33 (4)	-1.13 (2)	-0.06 (5)	-0.59 (3)	-0.20 (5)	-0.46 (4)
		Logan	21,900	-0,37 (4)	-0.74 (3)	0.86 (9)	-0.46 (4)	0.49 (7)	-0.04 (5)
		Lyon	5,900	-0.62 (3)	-0.82 (3)	-0.17 (5)	-1.17 (2)	-1.29 (1)	-0.82 (3)
		McCracken	59,000	1.44 (10)	1.03 (9)	1.97 (10)	1.93 (10)	1.93 (10)	1.66 (10)
		McLean	9,700	-0.46 (4)	-0.60 (3)	0.29 (7)	-0.67 (3)	-0.35 (4)	-0.36 (4)
		Marshall	21,900	-0.37 (4)	-0.46 (4)	-0.58 (3)	-0.73 (3)	-0.63 (3)	-0.56 (3)
		Marion	16,300	-0.03 (5)	-0.36 (4)	-0.38 (4)	-0.75 (3)	0.41 (7)	-0.22 (5)
		Meade	17,600	-1.10 (2)	-1.50 (1)	-1.95 (1)	-1.17 (2)	-1.29 (1)	-1.40 (1)
		Metcalfe	8,200	-1.03 (2)	-0.37 (4)	-1.54 (1)	-1.17 (2)	-1.29 (1)	-1.09 (2)
		Monroe	11,800	-0.62 (3)	0.21 (6)	0.90 (9)	-0.18 (5)	0.17 (6)	0.09 (6)
		Muhlenberg	29,700	-0.41 (4)	-0.62 (3)	0.45 (7)	-0.35 (4)	0.16 (6)	-0.15 (5)
		Nelson	24,000	-0.36 (4)	0.17 (6)	-0.47 (4)	-0.73 (3)	-0.82 (3)	-0.44 (4)
		Ohio	20,000	-0.81 (3)	-0.94 (2)	-0.10 (5)	-0.34 (4)	-0.10 (5)	-0.46 (4)
		Oldham	16,200	0.24 (6)	0.02 (6)	-1.14 (2)	-0.39 (4)	-0.08 (5)	-0.27 (5)
		Shelby	19,600	-0.69 (3)	0.01 (6)	-0.06 (5)	-0.33 (4)	0.02 (6)	-0.21 (5)
		Simpson	14,200	-0.29 (4)	0.28 (7)	1.69 (10)	-0.28 (4)	-0.06 (5)	0.27 (7)
		Spencer	5,500	-0.18 (5)	-0.75 (3)	-1.16 (2)	-1.17 (2)	-1.29 (1)	-0.91 (2)
		Todd	11,200	-0.39 (4)	-0.77 (3)	-0.06 (5)	-1.17 (2)	-1.29 (1)	-0.74 (3)
		Trigg	9,100	-0.17 (5)	-0.52 (4)	-0.23 (5)	-0.42 (4)	0.25 (6)	-0.22 (5)
		Trimble	5,500	-0.18 (5)	-1.85 (1)	-0.02 (5)	-1.17 (2)	-1.29 (1)	-0.90 (2)
		Union	16,200	-0.55 (3)	-0.35 (4)	0.42 (7)	-0.57 (3)	-0.12 (5)	-0.24 (5)
		Warren	61,600	1.08 (9)	1.30 (10)	1.27 (9)	1.27 (9)	1.14 (9)	1.21 (9)
		Washington	10,500	-0.53 (3)	1.04 (9)	-0.51 (4)	-1.17 (2)	-1.29 (1)	-0.49 (4)
		Webster	14,000	-1.04 (2)	-0.98 (2)	-0.06 (5)	-1.17 (2)	-1.29 (1)	-0.91 (2)
	2	Adair	14,200	-0.29 (4)	-0.57 (3)	-0.09 (5)	-0.83 (3)	-0.40 (4)	-0.44 (4)
		Anderson	10,600	-0.34 (4)	-0.13 (6)	0.07 (6)	-1.17 (2)	-1.29 (1)	-0.57 (3)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Kentucky (Cont.)	2 (Cont)	Bath	9,500	-0.89 (2)	-1.21 (2)	-0.98 (2)	-1.17 (2)	-1.29 (1)	-1.11 (2)
		Bell	32,500	1.08 (9)	-0.17 (5)	1.38 (10)	1.17 (9)	2.59 (10)	1.21 (9)
		Bourbon	18,700	0.37 (7)	0.10 (6)	2.07 (10)	-0.34 (4)	0.10 (6)	0.46 (7)
		Boyle	22,100	2.13 (10)	1.17 (9)	0.54 (8)	0.33 (7)	0.30 (7)	0.89 (9)
		Boyd	52,500	1.09 (9)	1.38 (10)	0.93 (9)	1.27 (9)	0.93 (9)	1.12 (9)
		Bracken	7,600	-0.50 (4)	-1.05 (2)	-2.31 (1)	-1.17 (2)	-1.29 (1)	-1.26 (2)
		Breathitt	15,300	-0.78 (3)	-0.66 (3)	-1.07 (2)	-1.17 (2)	-1.29 (1)	-1.00 (2)
		Carroll	8,600	-0.10 (5)	0.97 (9)	-0.11 (5)	0.19 (6)	1.97 (10)	0.58 (8)
		Carter	21,200	-0.94 (2)	-0.99 (2)	-0.52 (4)	-1.17 (2)	-1.29 (1)	-0.98 (2)
		Casey	13,900	-0.57 (3)	-0.98 (2)	-0.95 (2)	-0.68 (3)	-0.68 (3)	-0.77 (3)
		Clark	25,600	-0.18 (5)	0.28 (7)	0.40 (7)	-0.29 (4)	-0.28 (4)	-0.01 (5)
		Clay	20,500	-0.61 (3)	-0.96 (2)	-0.46 (4)	-0.51 (4)	-0.21 (5)	-0.55 (3)
		Clinton	8,700	-0.12 (5)	-0.46 (4)	-0.13 (5)	-0.39 (4)	0.40 (7)	-0.14 (5)
		Cumberland	6,900	-0.72 (3)	-0.09 (5)	1.35 (10)	-0.32 (4)	0.13 (6)	0.07 (6)
		Elliot	5,700	-0.92 (2)	-0.79 (3)	-1.20 (2)	-1.17 (2)	-1.29 (1)	-1.08 (2)
		Estill	13,200	-0.86 (2)	-0.93 (2)	-0.40 (4)	-0.73 (3)	-0.60 (3)	-0.70 (3)
		Fayette	174,400	7.08 (10)	3.50 (10)	2.85 (10)	2.67 (10)	1.34 (10)	3.49 (10)
		Fleming	11,500	-0.60 (3)	0.79 (8)	-0.66 (3)	-0.49 (4)	1.15 (9)	0.04 (6)
		Floyd	38,900	0.03 (6)	-0.45 (4)	0.12 (6)	-0.02 (5)	0.86 (9)	0.11 (6)
		Franklin	36,500	1.05 (9)	0.64 (8)	1.66 (10)	-1.17 (2)	-1.29 (1)	0.18 (6)
		Gallatin	4,400	-0.86 (2)	-0.47 (4)	0.56 (8)	-1.17 (2)	-1.29 (1)	-0.65 (3)
		Garrard	9,400	-0.66 (3)	-0.56 (3)	1.71 (10)	0.07 (6)	1.84 (10)	0.48 (7)
		Grant	11,200	-0.58 (3)	-0.77 (3)	0.51 (7)	-0.47 (4)	-0.35 (4)	-0.33 (4)
		Green	10,600	0.27 (7)	-0.13 (6)	1.26 (9)	-0.25 (5)	0.10 (6)	0.25 (6)
		Greenup	33,500	-0.83 (3)	-0.58 (3)	-0.80 (3)	0.43 (7)	0.01 (6)	-0.36 (4)
		Harlan	39,500	1.41 (10)	-0.93 (2)	0.40 (7)	0.63 (8)	0.48 (7)	0.40 (7)
		Harrison	14,700	0.25 (6)	0.21 (6)	1.12 (9)	0.42 (7)	0.93 (9)	0.59 (8)
		Jackson	10,300	-0.93 (2)	-1.85 (1)	-1.70 (1)	-1.17 (2)	-1.29 (1)	-1.39 (1)
		Jessamine	21,100	-0.74 (3)	-0.70 (3)	-0.22 (5)	-1.17 (2)	-1.29 (1)	-0.82 (3)
		Johnson	19,500	0.08 (6)	-0.92 (2)	-1.34 (1)	-0.82 (3)	0.42 (7)	-0.52 (4)
		Knott	16,200	-0.82 (3)	-1.85 (1)	-0.53 (1)	-1.17 (2)	-1.29 (1)	-1.33 (1)
		Knox	25,700	-0.68 (3)	-1.14 (2)	-1.33 (1)	-0.64 (3)	-0.59 (3)	-0.88 (2)
		Laurel	30,100	-0.42 (4)	-1.04 (2)	-0.21 (5)	-0.91 (2)	-0.70 (3)	-0.66 (3)
		Lawrence	11,600	0.13 (6)	0.76 (8)	-0.68 (3)	-0.25 (5)	-0.05 (5)	-0.02 (5)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Kentucky (Cont.)	2 (Cont)	Lee	6,700	-1.34 (1)	-0.04 (5)	-0.43 (4)	-1.17 (2)	-1.29 (1)	-0.85 (2)
		Leslie	11,900	-0.80 (3)	-1.34 (1)	-1.25 (2)	0.80 (8)	-0.55 (3)	-0.63 (3)
		Letcher	25,100	-0.15 (5)	-0.88 (2)	-0.55 (3)	-0.16 (5)	0.69 (8)	-0.21 (5)
		Lewis	12,800	-1.01 (2)	-1.37 (1)	-1.82 (1)	-1.17 (2)	-1.29 (1)	-1.33 (1)
		Lincoln	17,000	-0.71 (3)	-1.14 (2)	-0.45 (4)	-0.43 (4)	0.22 (6)	-0.50 (4)
		McCreary	13,800	-1.03 (2)	-0.53 (3)	-0.94 (2)	-1.17 (2)	-1.29 (1)	-0.99 (2)
		Madison	46,200	0.18 (6)	-0.01 (5)	1.10 (9)	0.16 (6)	0.33 (7)	0.35 (7)
		Magoffin	10,700	-0.94 (2)	-1.28 (1)	-1.13 (2)	-1.17 (2)	-1.29 (1)	-1.16 (2)
		Martin	10,400	-0.73 (3)	-1.27 (2)	-0.49 (4)	-1.17 (2)	-1.29 (1)	-0.99 (2)
		Mason	16,900	0.17 (6)	-0.06 (5)	1.42 (10)	0.79 (8)	1.68 (10)	0.80 (8)
		Menifer	4,400	-1.34 (1)	-1.85 (1)	-0.88 (2)	-1.17 (2)	-1.29 (1)	-1.31 (1)
		Mercer	17,400	-0.36 (4)	-0.11 (6)	1.31 (10)	-0.27 (4)	0.32 (7)	0.18 (6)
		Montgomery	17,100	-0.10 (5)	-0.43 (4)	0.64 (8)	-0.26 (4)	0.54 (8)	0.08 (6)
		Morgan	10,400	-0.73 (3)	-0.68 (3)	0.12 (6)	-1.17 (2)	-1.29 (1)	-0.75 (3)
		Nicholas	6,400	-0.34 (4)	0.04 (6)	-0.34 (4)	0.05 (6)	0.35 (7)	0.05 (6)
		Owen	7,900	-0.83 (3)	-0.31 (4)	0.09 (6)	0.06 (6)	1.28 (10)	0.06 (6)
		Owsley	5,200	-0.93 (2)	-0.68 (3)	-1.10 (2)	-1.17 (2)	-1.29 (1)	-1.03 (2)
		Pendelton	10,700	-0.74 (3)	-0.72 (3)	-1.13 (2)	-0.53 (3)	-0.37 (4)	-0.70 (3)
		Perry	27,600	-0.11 (5)	-0.75 (3)	-0.25 (5)	0.14 (6)	0.51 (7)	-0.09 (5)
		Pike	65,100	-0.16 (5)	-0.73 (3)	-0.47 (4)	-0.75 (3)	-0.35 (4)	-0.49 (3)
		Powell	8,200	-0.56 (3)	-1.11 (2)	-0.77 (3)	-1.17 (2)	-1.29 (1)	-0.98 (2)
		Pulaski	40,100	0.47 (7)	-0.34 (4)	-0.26 (4)	0.05 (6)	-0.30 (4)	-0.08 (5)
		Robertson	2,200	-1.34 (1)	-1.85 (1)	-2.31 (1)	-1.17 (1)	-1.29 (1)	-1.59 (1)
		Rock Castle	12,500	-0.66 (3)	0.09 (5)	-1.30 (1)	-0.55 (3)	-0.56 (3)	-0.60 (3)
		Rowan	16,700	1.47 (10)	-0.03 (5)	-0.04 (5)	0.29 (7)	0.68 (8)	0.47 (7)
		Russell	11,600	-0.63 (3)	0.24 (6)	0.95 (9)	-1.17 (2)	-1.29 (1)	-0.38 (4)
		Scott	18,400	-0.53 (3)	-0.53 (3)	0.09 (6)	-0.48 (4)	-0.43 (4)	-0.38 (4)
		Taylor	18,300	-0.53 (3)	-0.19 (6)	-0.93 (2)	-0.80 (3)	-0.81 (3)	-0.65 (3)
		Wayne	15,500	-0.52 (4)	-0.68 (3)	-0.27 (5)	-0.86 (2)	-0.84 (2)	-0.63 (3)
		Whitley	26,900	0.56 (8)	-0.05 (5)	0.74 (8)	-0.23 (5)	-0.25 (5)	0.16 (6)
		Wolfe	6,100	-0.99 (2)	0.14 (6)	0.79 (8)	-1.17 (2)	-1.29 (1)	-0.51 (4)
		Woodford	15,600	-0.11 (5)	0.09 (6)	0.52 (7)	0.27 (7)	0.15 (6)	0.18 (6)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Pennsylvania	5	Clearfield	76,800	0.05 (6)	0.20 (6)	-0.75 (3)	1.53 (10)	0.64 (8)	0.33 (7)
		Jefferson	46,400	-0.06 (5)	0.50 (7)	-0.95 (2)	0.51 (7)	-0.22 (5)	-0.04 (5)
	6	Allegheny	1,605,000	3.09 (10)	2.61 (10)	1.40 (10)	1.89 (10)	0.84 (9)	1.97 (10)
		Armstrong	76,200	-0.31 (4)	0.38 (7)	0.17 (6)	0.47 (7)	-0.43 (4)	0.06 (6)
		Beaver	208,200	0.09 (6)	0.73 (8)	0.64 (8)	0.90 (9)	-0.11 (5)	0.45 (7)
		Butler	127,500	-0.15 (5)	0.48 (7)	-0.21 (5)	-0.01 (5)	-0.37 (4)	-0.05 (5)
		Fayette	154,500	-0.03 (5)	0.59 (8)	0.03 (6)	0.93 (9)	-0.13 (5)	0.28 (7)
		Greene	37,100	0.15 (6)	-0.38 (4)	-0.27 (4)	0.54 (8)	-0.17 (5)	-0.03 (5)
		Indiana	83,900	-0.12 (5)	0.46 (7)	-0.88 (2)	0.23 (6)	-0.43 (4)	-0.15 (5)
		Lawrence	107,300	0.33 (7)	0.98 (9)	0.16 (6)	2.39 (10)	0.54 (8)	0.88 (9)
		Washington	210,900	0.25 (6)	0.62 (8)	-0.21 (5)	1.57 (10)	0.39 (7)	0.52 (7)
		Westmoreland	376,500	0.36 (7)	0.98 (9)	-0.08 (5)	0.92 (9)	0.14 (6)	0.47 (7)
	7	Clarion	40,600	-0.76 (3)	0.84 (9)	-0.13 (5)	-0.38 (4)	-0.69 (3)	-0.23 (5)
		Elk	37,800	0.24 (6)	0.40 (7)	0.19 (6)	2.03 (10)	2.09 (10)	0.99 (9)
		Forest	4,900	-0.04 (5)	-0.06 (5)	-2.31 (1)	-1.17 (2)	-1.29 (1)	-1.08 (2)
		Mercer	127,000	0.26 (7)	1.26 (9)	0.38 (7)	2.15 (10)	0.84 (9)	0.98 (9)
		Venango	63,600	0.77 (8)	1.01 (9)	-0.33 (4)	1.56 (10)	0.75 (8)	0.75 (8)
	9	Cambria	186,700	1.05 (9)	1.07 (9)	-0.10 (5)	1.94 (10)	1.07 (9)	1.01 (9)
		Somerset	77,200	-0.26 (4)	0.19 (6)	-0.59 (3)	0.54 (8)	0.26 (7)	0.03 (6)
West Virginia	1	Barbour	15,300	0.61 (8)	-1.06 (2)	1.81 (10)	1.00 (9)	1.02 (9)	0.68 (8)
		Boone	27,300	-0.33 (4)	-1.18 (2)	-1.38 (1)	-0.85 (2)	-0.75 (3)	-0.90 (2)
		Braxton	13,200	-0.53 (3)	-0.47 (4)	-1.83 (1)	-0.73 (3)	-0.71 (3)	-0.85 (2)
		Brooke	30,200	-0.71 (3)	-1.45 (1)	-0.43 (4)	-1.17 (2)	-1.29 (1)	-1.01 (2)
		Cabell	106,700	1.84 (10)	-1.50 (1)	1.45 (10)	2.66 (10)	2.74 (10)	1.44 (10)
		Calhoun	7,400	-0.48 (4)	-1.03 (2)	-0.60 (3)	0.28 (7)	0.65 (8)	-0.24 (5)
		Clay	9,700	-1.12 (2)	-1.85 (1)	-2.31 (1)	-1.17 (2)	-1.29 (1)	-1.55 (1)
		Doddridge	6,600	-1.34 (1)	-0.93 (2)	-1.35 (1)	-1.17 (2)	-1.29 (1)	-1.22 (2)
		Fayette	52,500	-0.25 (5)	-0.46 (4)	-0.51 (4)	-0.32 (4)	0.23 (6)	-0.26 (4)
		Gilmer	8,000	-1.34 (1)	-1.09 (2)	-1.52 (1)	-1.17 (2)	-1.29 (1)	-1.28 (1)
		Grant	8,900	0.33 (7)	0.19 (6)	-1.60 (1)	2.01 (10)	4.34 (10)	1.06 (9)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
West Virginia (Cont.)	1 (Cont)	Greenbrier	32,900	0.34 (7)	0.91 (9)	0.18 (6)	-0.07 (5)	0.04 (6)	0.28 (7)
		Hancock	40,400	0.87 (9)	0.85 (9)	0.50 (7)	1.83 (10)	0.37 (7)	0.88 (9)
		Harrison	74,800	0.42 (7)	0.99 (9)	0.73 (8)	1.32 (10)	1.21 (9)	0.93 (9)
		Jackson	21,900	-0.37 (4)	0.36 (7)	-0.58 (3)	0.08 (6)	0.18 (6)	-0.07 (5)
		Kanawha	229,500	2.15 (10)	1.24 (9)	0.14 (6)	1.47 (10)	1.11 (9)	1.22 (9)
		Lewis	17,700	-0.38 (4)	-0.14 (5)	1.25 (9)	0.15 (6)	0.10 (6)	0.20 (6)
		Lincoln	20,100	-0.81 (3)	-1.25 (2)	-1.99 (1)	-1.17 (2)	-1.29 (1)	-1.30 (1)
		Logan	46,100	0.55 (8)	-1.06 (2)	-1.21 (2)	0.25 (6)	0.60 (8)	-0.17 (5)
		McDowell	50,100	0.19 (6)	-1.00 (2)	-1.30 (1)	-0.14 (5)	1.05 (9)	-0.24 (5)
		Marion	63,600	0.67 (8)	0.34 (7)	1.16 (2)	1.36 (10)	0.98 (9)	0.90 (9)
		Marshall	38,500	-0.07 (5)	-0.27 (4)	0.48 (7)	1.06 (9)	1.00 (9)	0.44 (7)
		Mason	25,800	0.06 (6)	-0.44 (4)	-0.60 (3)	-0.23 (5)	-0.12 (5)	-0.26 (4)
		Mercer	65,900	1.37 (10)	0.08 (6)	-0.30 (4)	1.01 (9)	1.07 (9)	0.65 (8)
		Mingo	33,500	0.57 (8)	-0.58 (3)	-0.05 (5)	-0.79 (3)	-0.30 (4)	-0.23 (5)
		Monongalia	68,800	8.85 (10)	5.72 (10)	2.73 (10)	3.42 (10)	1.79 (10)	4.50 (10)
		Monroe	11,500	-0.41 (4)	-0.27 (4)	-0.66 (3)	-1.17 (2)	-1.29 (1)	-0.76 (3)
		Nicholas	24,000	-0.36 (4)	-0.33 (4)	-1.00 (2)	-0.36 (4)	0.68 (8)	-0.27 (4)
		Ohio	61,800	4.97 (10)	2.76 (10)	0.75 (3)	5.47 (10)	3.49 (10)	3.49 (10)
		Pleasants	7,600	-0.50 (4)	0.54 (8)	0.18 (6)	-1.17 (2)	-1.29 (1)	-0.45 (4)
		Pocahontas	8,500	0.16 (6)	-0.42 (4)	-0.83 (3)	-0.60 (3)	0.44 (7)	-0.25 (5)
		Preston	26,700	-0.62 (3)	-1.17 (2)	-1.13 (2)	-0.70 (3)	-0.34 (4)	-0.79 (3)
		Putnam	30,100	-1.13 (2)	-0.44 (4)	-1.05 (2)	-1.17 (2)	-1.29 (1)	-1.02 (2)
		Raleigh	75,500	1.93 (10)	0.32 (7)	-0.14 (5)	1.35 (10)	2.11 (10)	1.12 (9)
		Randolph	25,900	2.03 (10)	0.96 (9)	-0.60 (3)	2.07 (10)	3.22 (10)	1.54 (10)
		Ritchie	10,300	-0.72 (3)	-0.08 (5)	-1.08 (2)	-1.17 (2)	-1.29 (1)	-0.87 (2)
		Roane	14,800	0.53 (8)	-0.62 (3)	-1.46 (1)	0.35 (7)	1.65 (10)	0.09 (6)
		Summers	13,500	0.39 (7)	-0.50 (4)	0.03 (6)	0.49 (7)	3.00 (10)	0.68 (8)
		Taylor	15,000	-0.49 (4)	-0.64 (3)	0.21 (6)	0.91 (9)	2.05 (10)	0.41 (7)
		Tucker	7,400	-0.48 (4)	0.61 (8)	-0.60 (3)	-1.17 (2)	-1.29 (1)	-0.59 (3)
		Tyler	9,800	-0.47 (4)	-1.23 (2)	-0.38 (4)	-0.47 (4)	-0.61 (3)	-0.63 (3)
		Upshur	21,000	-0.53 (3)	-0.13 (5)	-0.52 (4)	-0.34 (4)	0.39 (7)	-0.23 (5)
		Wayne	38,200	-1.23 (2)	8.62 (10)	-0.82 (3)	-1.17 (2)	-1.29 (1)	0.82 (8)
		Webster	10,100	-0.71 (3)	-1.25 (2)	-1.68 (1)	-0.11 (5)	1.77 (10)	-0.40 (4)
		Wetzel	20,800	-0.21 (5)	1.94 (10)	-0.19 (5)	0.43 (7)	0.06 (6)	0.40 (7)

TABLE 2.2.-2 (Continued)

ORBES COUNTIES LISTED BY STATE, HEALTH SYSTEMS AGENCY (HSA), Z SCORE (DECILE)

STATE	HSA No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
West Virginia (Cont.)	1 (Cont)	Wirt	4,400	-0.86 (2)	-0.47 (4)	-2.31 (1)	-1.17 (2)	-1.29 (1)	-1.22 (2)
		Wood	86,400	0.90 (9)	0.54 (8)	0.46 (7)	1.28 (10)	1.03 (9)	0.84 (9)
		Wyoming	32,200	-0.41 (4)	-0.72 (3)	-1.53 (1)	-0.66 (3)	-0.58 (3)	-0.78 (3)

TABLE 2.2.-3

ORBES COUNTIES IN THE HIGHEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
ILLINOIS	2	Bureau	36,700				2.02	1.70	
		Fulton	42,400				1.46		
		Knox	61,300				1.73		
		Marshall	13,100		1.85				
		Peoria	195,300	2.42			2.44	1.74	2.12
	3	Adams	71,000	1.30				1.54	
		Calhoun	5,500			2.28			
		Morgan	36,500		1.64	1.66	1.43	1.53	1.40
		Sangamon	161,200	2.42			2.42		1.64
		Schuyler	7,900				1.67	2.62	
	4	Champaign	163,100	1.36			2.11		
		Douglas	19,000		1.66				
		Ford	15,000					1.61	
	5	Alexander	11,500				3.16	2.22	
		Edwards	7,500		1.38				
		Fayette	20,700					1.95	
		Franklin	40,900					1.33	
		Hardin	5,000			1.47		1.87	
		Randolph	32,000					1.39	
		Richland	16,900	1.81			1.78	1.82	1.50
		Saline	26,300					1.50	
		White	16,400	1.39					
		Williamson	51,800					1.32	
INDIANA	1	Allen	280,600				1.50		
		Wells	25,000	2.32			2.07	2.03	
	2	Boone	32,000			2.22			
		Hancock	40,300			1.45			
		Marion	792,300	3.38	2.62	4.79	1.94		2.74
		Tippecanoe	109,400	1.68		4.83	1.54		1.95
		Tipton	16,000				1.52	1.69	
		White	21,900		1.47				

TABLE 2.2.-3 (Continued)

ORBES COUNTIES IN THE HIGHEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Indiana (Cont.)	3	Daviess	26,700				1.35		
		Decatur	23,100			2.33			
		Jackson	34,200			1.75			
		Knox	40,900		1.41	2.16	1.79	1.42	1.55
		Vanderburgh	168,600	2.24	1.77	2.53	2.09	1.85	2.10
		Vigo	114,400		1.32				
Ohio	1	Hamilton	923,900	3.67		2.35	1.28		1.83
(Kentucky)	(Kentucky)	Campbell	85,000			1.55			
(Kentucky)	(Kentucky)	Kenton	129,100			1.56			
	2	Montgomery	605,900	1.61	1.31		1.44		
	3	Allen	110,800				2.14		
		Hardin	31,700			2.86			
	5	Franklin	833,300	2.68	2.48	2.09			1.75
		Marion	66,900	1.46					
		Morrow	23,900		4.49				
		Wyandot	22,600		2.17				
	6	Gallia	27,500	1.91			2.13	2.08	1.29
		Jackson	28,700		1.53				
		Jefferson	96,200				2.57		
		Muskingum	80,100			2.10	1.49	2.01	1.38
	7	Stark	372,400				1.49		
	8	Summit	553,600	2.15	1.38				
	10	Mahoning	303,700	1.97			1.58		
	5	Clearfield	76,800				1.53		
Pennsylvania	6	Allegheny	1,605,000	3.09	2.61	1.40	1.89		1.97
		Lawrence	107,300				2.39		
		Washington	210,900				1.57		

TABLE 2.2.-3 (Continued)

ORBES COUNTIES IN THE HIGHEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Pennsylvania (Cont.)	7	Elk	37,800				2.03	2.09	
		Mercer	127,000				2.15		
		Venango	63,600				1.56		
	9	Cambria	186,700				1.94		
West Virginia	1	Barbour	15,300			1.81			
		Cabell	106,700	1.84		1.45	2.66	2.74	1.44
		Grant	8,900				2.01	4.34	
		Hancock	40,400				1.83		
		Harrison	74,800				1.32		
		Kanawha	229,500	2.15			1.47		
		Marion	63,600				1.36		
		Mercer	65,900	1.37					
		Monongalia	68,800	8.85	5.72	2.73	3.42	1.79	4.50
		Ohio	61,800	4.97	2.76		5.47	3.49	3.49
		Raleigh	75,500	1.93			1.35	2.11	
		Randolph	25,900	2.03			2.07	3.22	1.54
		Roane	14,800					1.65	
		Summers	13,500					3.00	
		Taylor	15,000					2.05	
		Wayne	38,200		8.62				
		Webster	10,100					1.77	
		Wetzel	20,800		1.94				
		Wood	86,400				1.28		
Kentucky	1	Banen	30,500			2.24			
		Caldwell	13,000			1.57			
		Christian	68,000				1.55	1.48	
		Crittenden	9,400			1.71			
		Daviess	81,000				1.87	1.74	
		Fulton	9,600			2.29			
		Hardin	73,600				1.74	2.22	
		Hickman	6,800				1.42	1.34	
		Hopkins	41,500	1.84					
		Jefferson	695,300	2.73	1.34		1.32		1.43

TABLE 2.2.-3 (Continued)

ORBES COUNTIES IN THE HIGHEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Kentucky (Cont.)	1 (Cont.)	McCraken	59,000	1.44		1.97	1.93	1.93	1.66
		Simpson	14,200			1.69			
		Warren	61,600		•1.30				
	2	Bell	32,500			1.38			
		Bourbon	18,700			2.07			
		Boyd	52,500		1.38				
		Boyle	22,100	2.13					
		Carroll	8,600					1.97	
		Cumberland	6,900			1.35			
		Fayette	174,400	7.08	3.50	2.85	2.67	1.34	3.49
		Franklin	36,500			1.66			
		Garrard	9,400			1.71		1.84	
		Harlan	39,500	1.41					
		Mason	16,900			1.42		1.68	
		Mercer	17,400			1.31			
		Owen	7,900					1.28	
		Rowan	16,700	1.47					

TABLE 2.2.-4

ORBES COUNTIES IN THE LOWEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Illinois	2	Henderson	8,300		-1.85	-1.55		-1.29	-1.34
		Marshall	13,100					-1.29	
		Putnam	5,400					-1.29	
		Stark	7,200					-1.29	
		Woodford				-1.66			
	3	Brown	5,500					-1.29	
		Calhoun	5,500					-1.29	
		Menard	10,600					-1.29	
		Scott	6,100			-1.28		-1.29	
	4	Clark	16,100			-1.28		-1.29	
		Cumberland	10,300					-1.29	
		Moultrie	13,000					-1.29	
		Shelby	22,900			-1.76			
	5	Clay	14,900			-1.46			
		Edwards	7,500					-1.29	
		Gallatin	7,300					-1.29	
		Jasper	10,800					-1.29	
		Johnson	8,700					-1.29	
		Pope	4,300					-1.29	
		Pulaski	8,800		-1.85			-1.29	
	11	Monroe	18,900			-1.31		-1.29	
	2	Benton	11,200					-1.29	
		Carroll	18,200					-1.29	
		Fountain	18,600					-1.29	
		Franklin	17,600					-1.29	
		Union	6,700			-1.37		-1.29	
		Warren	8,500		-1.85	-1.57			
	3	Brown	9,700					-1.29	
		Crawford	8,700			-2.31		-1.29	-1.40
		Harrison	23,100			-1.49			

TABLE 2.2.-4 (Continued)

ORBES COUNTIES IN THE LOWEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Illinois (Cont.)	3 (Cont)	Jennings	20,600			-1.39			
		Martin	11,000					-1.29	
		Ohio	4,600					-1.29	
		Owen	13,100		-1.39			-1.29	
		Parke	15,600					-1.29	
		Pike	12,100		-1.35	-1.79		-1.29	-1.32
		Posey	22,900					-1.29	
		Spencer	17,700					-1.29	
		Switzerland	6,600			-1.35		-1.29	
		Warrick	33,300					-1.29	
Ohio (Kentucky)	1 (Kentucky)	Adams	22,700		-1.31				
		Boone	36,200					-1.29	
		Warren	86,900					-1.29	
	2	Preble	35,900					-1.29	
		Shelby	40,000		-1.70				
	5	Union	25,700		-1.38				
	6	Monroe	15,800		-1.46			-1.29	
		Morgan	13,400					-1.29	
		Noble	10,800					-1.29	
		Perry	30,000					-1.29	
		Vinton	10,500	-1.34				-1.29	
		Carroll	24,600					-1.29	
		Holmes	24,600			-1.28			
Pennsylvania	7	Forest	4,900			-2.31		-1.29	
West Virginia	1	Boone	27,300			-1.38			
		Braxton	13,200			-1.83			
		Brooke	30,200		-1.45				
		Cabell	106,700		-1.50				
		Clay	9,700		-1.85	-2.31		-1.29	-1.55
		Doddridge	6,600	-1.31		-1.35		-1.29	
		Gilmer	8,000	-1.34		-1.52		-1.29	-1.28

TABLE 2.2.-4 (Continued)

ORBES COUNTIES IN THE LOWEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
West Virginia (Cont.)	1 (Cont)	Grant	8,900			-1.60			
		Lincoln	20,100			-1.99		-1.29	-1.30
		McDowell	50,100			-1.30			
		Monroe	11,500					-1.29	
		Pleasants	7,600					-1.29	
		Putnam	30,100					-1.29	
		Ritchie	10,300					-1.29	
		Roane	14,800			-1.46			
		Tucker	7,400					-1.29	
		Wayne	38,200					-1.29	
		Webster	10,100			-1.68			
		Wirt	4,400			-2.31		-1.29	
		Wyoming	32,200			-1.53			
Kentucky	1	Ballard	8,300		-1.85	-1.55		-1.29	
		Bullitt	31,600			-1.31		-1.29	
		Butler	10,200		-1.85			-1.29	
		Carlisle	5,400	-1.34				-1.29	
		Edmondson	9,100		-1.85			-1.29	
		Hancock	7,300					-1.29	
		Henry	11,400					-1.29	
		Larue	11,300					-1.29	
		Lyon	5,900					-1.29	
		Meade	17,600		-1.50	-1.95		-1.29	-1.40
		Metcalfe	8,200			-1.54		-1.29	
		Spencer	5,500					-1.29	
		Todd	11,200					-1.29	
		Trimble	5,500		-1.85			-1.29	
		Washington	10,500					-1.29	
		Webster	14,000					-1.29	
	2	Anderson	10,600					-1.29	
		Bath	9,50					-1.29	
		Bracken	7,600			-2.31		-1.29	
		Breathitt	15,300					-1.29	
		Carter	21,200					-1.29	
		Elliot	5,700					-1.29	

TABLE 2.2.-4 (Continued)

ORBES COUNTIES IN THE LOWEST DECILE OF HEALTH SERVICES AVAILABILITY (Based on Z-Scores)

STATE	HEALTH SYSTEMS AGENCY No.	COUNTY	POPULATION	MD'S	DENTISTS	PHARMACISTS	NURSES	BEDS	MEAN Z SCORE
Kentucky (Cont.)	2 (Cont.)	Franklin	36,500					-1.29	
		Gallatin	4,400					-1.29	
		Jackson	10,300		-1.85	-1.70		-1.29	-1.39
		Jessamine	21,100					-1.29	
		Johnson	19,500			-1.34			
		Knott	16,200		-1.85	-1.53		-1.29	-1.33
		Knox	25,700			-1.33			
		Lee	6,700	-1.34				-1.29	
		Leslie	11,900		-1.34				
		Lewis	12,800		-1.37	-1.82		-1.29	-1.33
		McCreary	13,800					-1.29	
		Magoffin	10,700		-1.28			-1.29	
		Martin	10,400					-1.29	
		Menifee	4,400	-1.34	-1.85			-1.29	-1.31
		Morgan	10,400					-1.29	
		Owsley	5,200					-1.29	
		Powell	8,200					-1.29	
		Robertson	2,200	-1.31	-1.85	-2.31	-1.17	-1.29	-1.59
		Rock Castle	12,500			-1.30			
		Russell	11,600					-1.29	
		Wolfe	6,100					-1.29	

TABLE 2.2.-5

GEOGRAPHIC DISTRIBUTION OF EMPLOYED PHYSICIAN ASSISTANTS

Geographic Location	Percent of PAs*	Geographic Location	Percent of PAs*
Northeast	(20.6)	North Central	(20.6)
Connecticut	2.2	Illinois	1.6
Maine	1.2	Indiana	1.8
Massachusetts	2.2	Iowa	1.8
New Hampshire	1.0	Kansas	1.8
New Jersey	0.6	Michigan	3.7
New York	7.7	Minnesota	0.7
Pennsylvania	4.7	Missouri	1.3
Rhode Island	0.2	Nebraska	1.0
Vermont	0.7	North Dakota	0.8
South	(34.7)	Ohio	3.4
Alabama	1.7	South Dakota	0.7
Arkansas	0.4	Wisconsin	2.0
Delaware	0.2	West	(21.6)
District of Columbia	1.1	Alaska	1.6
Florida	4.6	Arizona	1.5
Georgia	3.8	California	8.2
Kentucky	1.3	Colorado	2.4
Louisiana	0.3	Hawaii	0.3
Maryland	2.5	Idaho	0.5
Mississippi	0.3	Montana	0.3
North Carolina	5.4	Nevada	0.5
Oklahoma	3.3	New Mexico	1.5
South Carolina	1.7	Oregon	0.6
Tennessee	1.0	Utah	0.6
Texas	5.0	Washington	3.3
Virginia	1.2	Wyoming	0.4
West Virginia	1.0		
		Outside United States	(2.6)

*Percents are based on 3167.

3. HEALTH ASPECTS OF COAL UTILIZATION FOR ENERGY PRODUCTION

3.1 MINING

In addition to miners, coal workers include mine construction workers, preparation plant workers, tipple workers, and personnel employed in mine-related repair shops. Underground miners, as a group, are subjected to the highest accident risks of anyone involved in either the coal or nuclear fuel cycles. Over the past three decades, annual fatality frequency rates (accidental deaths) among bituminous miners reached 1.37 fatalities per million man hours worked (1968) (1). Overall, however, among underground miners there is evidence of a downward trend in deaths per tons extracted during this period (2). Nonetheless, the fact that recent accidental death rates in U.S. underground mines are two to four times those of other industrialized countries has prompted the American Public Health Association to label the existing situation "a national disgrace" (3).

The exposures and working conditions of miners in the ORBES Region are highly variable depending on job responsibilities, mine location, and mining methods. As noted in the Office of Technology Assessment's The Direct Use of Coal:

> "Their (coal workers) jobs vary. Some operate multi-million dollar earth excavators; others load coal by shovel. Some sweat all day; others never do. Many are highly skilled; others aren't. Their work environments range from air-conditioned, bucket-seated dragline cabs to 20-inch coal seams where the machine operator lies on his back most of the day" (4).

In terms of risk, mining method is undoubtedly the most important factor. Surface mining of coal appears to be an inherently safer activity than deep mining. The most recent (1977) Mine Enforcement Safety Administration (MESA) data indicate that underground mines have a fatality frequency rate of 0.40 deaths per million employee-hours* whereas surface mines experienced 0.24 deaths per million employee-hours (5). Because surface mining is much more efficient than deep mining, the difference becomes magnified when one considers deaths per million tons mined as the basis for comparison. Fatality frequencies for 1977 were 0.35 and 0.07 deaths per million tons of bituminous coal mined by deep and surface methods, respectively. Moreover, these comparisons are only for accidental deaths. If one takes into account diseases attributable to occupational exposures (pneumonoconiosis, stomach cancer), the health impacts of deep mining are much more severe than those of surface mining.

The first task of the public and occupational health impact assessment consists of synthesizing a baseline of impacts attributable to electric power generation in the ORBES Region for the base year 1975. Such a baseline provides a frame of reference with which to gage the severity of scenario impacts for 1985 and 2000.

Baseline formulation is readily handled for accidental deaths resulting from coal extraction. The 1975 mining fatalities reported by MESA (6) in the six ORBES states due to the mining of bituminous coal is shown in Table 3.1.-1.

---

* Includes deep mine workers both underground and at the surface.

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The 110 deaths reported in Table 3.1.-1 are attributable to all end-uses of the 606 million tons of bituminous coal mined during 1975 in the six ORBES States (Table 3.1.-2). The following questions must be answered:

a.) What proportion of the 606 million tons was used to "fire" the 1975 generation capacity of the ORBES Region?

b.) To what extent, if any, were coals mined outside of the six ORBES States used to "fire" the 1975 capacity of the ORBES Region and if so, what are their 1975 fatality frequency inputs to Table 3.1.-1?

The coal-fired generating capacity of the ORBES Region in 1975 is listed below(11):

Sub-Region	MWe
Illinois	10,512
Indiana	10,114
Kentucky	10,948
Ohio	17,034
Pennsylvania	9,691
West Virginia	11,966
ORBES	70,265

One could conceivably use these megawattages to calculate a coal demand for the Region in 1975. However, such a calculation would entail several assumptions, including: (1) the average Btu content of the coal utilized, (2) the average load factor of the plants in question, and (3) the average thermal efficiency of the plants in question. Clearly, the results of such a calculation would be extremely crude and unacceptable for baseline formulation. Moreover, the task of estimating a representative load (capacity) factor for all of the ORBES coal-fired power plants would, in and of itself, be a monumental task. We, therefore, must utilize another approach to back-calculate the coal tonnage actually used for the 1975 ORBES capacity of 70,265 MWe.

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The National Coal Association publishes an annual accounting of coal purchases made by each power plant in the United States. Such purchases frequently exceed coal consumption because of stockpiling. However, since coal purchases do affect demand and are intended for eventual use in electricity generation, the health effects attributable to an annual purchase can legitimately be considered part of the impact of the capacity configuration prevailing in that same year. Table 3.1.-3 presents the quantities of coal delivered in 1975 to electric power plants (commercial) within each of the ORBES Sub-regions. For example, the electric utilities of the Illinois ORBES Sub-region purchased 22.82 million tons of coal in 1975, 19.79 million tons of which originated within the state of Illinois. The remainder of the coal purchased in the ORBES portion of the state was obtained from mines in Kentucky, Indiana, and several other states outside the ORBES Region. The identification of state contributions to ORBES annual purchase for power generation (Table 3.1.-3) is vital to the baseline formulation since states often have accidental fatality rates which are appreciably different from one another (Table 3.1.-6).

Table 3.1.-3 indicates the fact that 3.8% (5.95/156.98 x 100) of the coal tonnage delivered to ORBES plants in 1975 originated from mines outside of the six ORBES States. (See column labeled "other.")

Knowing the total amount of coal purchased by ORBES utilities, we must make a reasonable assumption regarding the mix of surface vs. deep mined coals comprising the 1975 ORBES power plant purchases. Henceforth, we shall assume that the total coal delivery from a given state (Table 3.1.-3) is comprised of surface and deep mined coals in the state-specific proportions presented in Table 3.1.-2 for all the coal mined in 1975. Utilizing the

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1975 data from Table 3.1.-2 and augmenting it with comparable data for the seven non-ORBES states that sold coal to ORBES power plants in 1975 results in amounts shown in Table 2.1.-4. Table 3.1.-5 is the result of applying the percentages of Table 3.1.-4 to the state-specific coal deliveries of Table 3.1.-3 (bottom row). Table 3.1.-5 details the amount of coal delivered to ORBES power plants by the assumed mix of extraction methods.

The accidental fatality rates in the states supplying coal to the ORBES Region are shown in Tables 3.1.-6 and 3.1.-7.

We can now proceed with the calculation of accidental mining fatalities attributable to the 70,265 MWe capacity of the ORBES Region in 1975. Applying the 1975 site-specific, mining method-specific fatality rates of Tables 3.1.-6 and 3.1.-7 to the 1975 state-specific, method-specific tonnages purchased by ORBES plants (Tables 3.1.-5) yields the number of accidental deaths by state and mining method which is shown in Table 3.1.-8.

The number of non-fatal disabling injuries attributable to the 1975 coal purchases of ORBES power plants can be calculated by applying 1975 non-fatal disabling injury rates for the six ORBES States (Table 3.1.-9) as well as the other coal supplying states (Table 3.1.-10) to the coal delivery data (Table 3.1.-5). The results are shown in Table 3.1.-11. Similarly, application of non-fatal and non-disabling injury rates (Tables 3.1.-10 and 3.1.-12) to the coal delivery data yields the number of non-disabling injuries attributable to the 1975 coal purchases of ORBES power plants, shown in Table 3.1.-13.

The final area of health impacts from coal extraction is occupational disease. In their most recent analysis, researchers at the Brookhaven National Laboratory (13) concluded that results of the Rockette study (14) are the best available for quantifying this segment of the extraction sector.

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We concur with this judgment. Coupling Rockette's 4.9×10^{-4} excess disease deaths per person-year with productivity figures of the 1950's (450 man-years per 10^6 tons for 1959 and 750 man-years per 10^6 tons for 1952) yields a range of 0.22 to 0.37 attributable deaths per million tons mined. However, such an approach only provides a means of assessing the disease impacts in relation to the mining productivity of a previous time.

For the purposes of prediction, Morris et al. (13) advocate the application of a "linear extrapolation factor of 3.5" to past estimates of excess disease deaths in study populations. (The 3.5 factor is actually an upper limit, since the dose-effect function is believed to be concave.) The extrapolation factor is based upon the fact that dust concentrations in coal mines have been reduced by a factor of 3 to 4 in recent years. Dividing Rockette's 4.9×10^{-4} excess death estimate by the extrapolation factor of 3.5 yields 1.4×10^{-4} excess deaths per person-year for post-1970 miner populations (Table 3.1.-14). By applying the 1976 productivity estimate of 1900 tons per person-year, researchers at Brookhaven (13) arrived at an excess death rate of 0.07 excess deaths per million tons mined (Table 3.1.-14). They have identified this figure as the best estimate and have provided a range of zero to 0.47 excess deaths per million tons based on the work of Hollingsworth (15) and Morris (16) for the upper limit and Liddell (17) for the lower limit.

If we multiply the 74.63 million deep-mined tons purchased by ORBES power plants in 1975 by the disease death estimate of 0.07 excess deaths per million tons mined, we arrive at an estimate of 5.2 excess deaths in 1975.

We must now address the question of disability via occupationally acquired disease. Bohm, Moore, and Schmidt-Bleek (18) have estimated that 900 to 1800 miners were newly disabled by pulmonary disease between 1970 and 1971.

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Morris *et al.* (13) have utilized this finding in conjunction with an annual production figure of 350 million tons to estimate 2.6 - 5.1 cases of attributable disability (disease) per million tons mined. For the purpose of quantifying 1975 impacts, we will use the mid-point value of 3.8 cases attributable to the 1975 ORBES generating capacity. Morris *et al.*, sanction the use of Bohm *et al.*, data because an estimate of 2.6 to 5.1 attributable cases is more consistent with the Rockette-based mortality estimate of 0.07 deaths than WASH 1224's (19) estimate of 0.202 cases per million tons.

If we multiply the 74.63 million deep mined tons purchased by ORBES power plants in 1975 by the disease disability estimate (3.8 cases per million tons mined), we arrive at an estimate of 283.6 cases for 1975.

Summarizing our baseline calculations, we see that in terms of human health the level of coal extraction required to "fire" the 1975 ORBES generating capacity of 70,265 MWe resulted in the following health costs rounded-up to the next higher whole number under the assumption that a fractional part of an attributable effect is necessary for the effect:

37 accidental deaths
2,656 non-fatal disabling injuries
2,198 non-disabling injuries
6 excess disease deaths
284 disease disabilities

In recent years health effects researchers have tended to "normalize" the health effects of electric power production to a "standard" 1000 MWe plant operated over the course of one year (20, 21, 22, 23). By dividing each of our baseline calculations by 70,265, we have normalized our

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calculations to a "standard" 1000 MWe plant. The results are shown in Table 3.1.-15. We may compare these figures with those of Comar and Sagan (20) for the number of deaths and injuries per year associated with operation of a 1000 MWe power plant:

0.45 to 0.99 accidental deaths
0 to 3.5 disease deaths
22 to 49 accidental injuries
0.6 to 48 disease injuries

Or, we may compare our results to those of Bliss _et_ _al_. (21):

1.98 deaths per 1000 MWe Year
98.9 injuries per 1000 MWe Year

Or we may compare our results to those obtained at Brookhaven (22), all expressed per 6.6×10^9 KWh_e generated (1000 MW_e capacity plant operating for a year at a load factor of 75%):

Underground mining:

0.6 accidental deaths
0 to 7 deaths from disease
30 accidental injuries
0.5 to 7 cases of disabling PMF
20 cases of CWP
0 to 70 incidents of miscellaneous impairment

Surface mining:

0.3 accidental deaths
13 injuries (mean lost time = 50 days)

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Finally, we may also compare our results to those of an American Medical Association report which summarized data from several authors (23):

0.45 - 1.24 accidental deaths per 1000 MWe per Year

0 - 4.8 disease deaths per 1000 MWe per Year

22 - 80 accidental injuries per 1000 MWe per Year

0.6 - 48 disease injuries per 1000 MWe per Year

Health impacts attributable to the mining of the coal burned in the ORBES region power plants during the years 1985 and 2000 were estimated. The statistics are based on the 1975 health casualty rates shown in Table 3.1.-15 and the projected installed coal-fired generating capacity in the region for each of the twelve scenarios listed in Table 3.1.-16. The results are shown in Table 3.1.-17. Since installed generating capacity is identical for each scenario in 1985, the impacts are also the same for each alternative. Estimated health impacts expected in 1985 are: 53 accidental deaths; 3813 disabling injuries; 3156 non-disabling injuries due to firing of coal to generate power in the ORBES region. Eight excess deaths and 408 disablements will be due to illness incurred by the miners.

For the year 2000, the health impacts will range from a low for Scenario 6 (very low energy growth) to a high for Scenario 7 (high energy growth) as follows: 49 to 87 accidental deaths; 3514 to 6334 disabling injuries; 2908 to 5242 non-disabling injuries; and, due to illness, 7 to 13 excess deaths and 376 to 677 disease disabilities.

All of the estimates are based on a constant health impact rate using 1975 as the base year, a constant thermal efficiency in the ORBES power plants, and similar extraction technology mix; i.e., strip and deep mining.

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TABLE 3.1.-1

1975 MINING FATALITIES

State	Surface Mines		Underground Mines	
	No. of Deaths	Deaths/10^6 tons	No. of Deaths	Deaths/10^6 tons
Illinois	2	0.07	6	0.19
Indiana	3	0.12	0	0.00
Kentucky	10	0.17	35	0.60
Ohio	1	0.03	4	0.26
Pennsylvania	6	0.16	11	0.25
West Virginia	3	0.15	29	0.33
Total	25	0.12	85	0.36

SOURCE: Reference (6).

TABLE 3.1.-2

BITUMINOUS COAL PRODUCTION IN THE UNITED STATES AND THE ORBES STATES
(million short tons)

	1972	1973	1974	1975	1976	1977
SURFACE MINING						
Illinois	31.46	28.68	27.02	27.63	26.89	24.06
Indiana	22.10	24.17	23.33	24.90	24.90	26.35
Kentucky	52.79	53.37	56.87	59.17	63.03	72.81
Ohio	31.99	28.84	31.05	32.08	30.73	33.63
Pennsylvania	18.55	26.40	34.01	37.86	41.90	47.87
West Virginia	15.29	17.36	19.44	19.85	21.55	21.11
Total	172.18	178.82	191.72	201.49	209.00	225.83
USA	241.03	266.27	297.44	327.87	361.18	408.52
DEEP MINING						
Illinois	31.33	32.54	31.12	31.97	30.87	29.59
Indiana	1.34	0.81	0.13	0.18	0.43	0.55
Kentucky	49.97	55.44	55.25	58.09	56.53	54.16
Ohio	16.55	15.78	14.73	15.24	16.61	14.31
Pennsylvania	47.77	46.33	42.29	44.57	44.05	38.91
West Virginia	98.55	93.65	80.39	86.78	86.70	73.00
Total	245.51	244.55	223.91	236.83	235.19	210.52
USA	287.06	285.21	263.40	278.13	280.52	256.89

SOURCE: References (5), (6), (7), (8), (9), (10).

TABLE 3.1.-3

1975 COAL DELIVERIES* TO COMMERCIAL ELECTRIC POWER PLANTS IN THE ORBES REGION
(millions of tons)

	STATE OF ORIGIN							
SUB-REGION	IL	IN	KY	OH	PA	WV	OTHER**	TOTAL
Illinois	19.79	0.38	1.17	--	--	--	1.48	22.82
Indiana	0.94	17.73	5.04	--	--	0.07	0.42	24.20
Kentucky	1.97	1.58	21.66	--	--	--	0.27	25.48
Ohio	--	0.03	6.18	20.07	1.54	5.34	1.85	35.01
Pennsylvania	--	--	0.78	0.02	19.57	2.81	--	23.18
West Virginia	--	--	2.57	0.39	0.18	21.22	1.93	26.29
Total ORBES	22.70	19.72	37.40	20.48	21.29	29.44	5.95	156.98

* Deliveries may exceed consumption due to stockpiling.

** ORBES purchases from other states amounted to the following quantities in 1975:

Mining State	1975 ORBES Purchase
Virginia	1.68 x 10^6 tons
Wyoming	1.52 x 10^6 tons
Montana	1.31 x 10^6 tons
Maryland	0.80 x 10^6 tons
Utah	0.50 x 10^6 tons
Tennessee	0.13 x 10^6 tons
Colorado	0.01 x 10^6 tons
Total	5.95 x 10^6 tons

SOURCE: Adapted from Reference (12).

TABLE 3.1.-4

1975 BITUMINOUS COAL PRODUCTION BY MINING METHOD

MINING STATES	MILLIONS OF TONS MINED	PERCENT	
		SURFACE	DEEP
Illinois	59.60	46.36	53.64
Indiana	25.08	99.28	0.72
Kentucky	117.26	50.46	49.54
Ohio	47.32	67.79	32.21
Pennsylvania	82.43	45.93	54.07
West Virginia	106.63	18.62	81.38
Virginia	28.85	34.84	65.16
Wyoming	22.60	97.74	2.26
Montana	22.12	100.00	0.0
Maryland	2.11	96.00	4.00
Utah	7.06	0.0	100.00
Tennessee	6.25	54.08	45.92
Colorado	8.11	57.71	42.29

SOURCE: Reference (6).

TABLE 3.1.-5

1975 COAL DELIVERIES TO ORBES POWER PLANTS BY STIPULATED MIX OF MINING METHODS

(millions of tons)

MINING STATES	ORBES POWER PLANT PURCHASES	SURFACE MINED	DEEP MINED
Illinois	22.70	10.52	12.18
Indiana	19.72	19.58	0.14
Kentucky	37.40	18.87	18.53
Ohio	20.48	13.88	6.60
Pennsylvania	21.29	9.78	11.51
West Virginia	29.44	5.48	23.96
Virginia	1.68	0.59	1.09
Wyoming	1.52	1.49	0.03
Montana	1.31	1.31	0.0
Maryland	0.80	0.77	0.03
Utah	0.50	0.0	0.50
Tennessee	0.13	0.07	0.06
Colorado	0.01	0.006	0.004
Total	156.98	82.35	74.63

NOTES: Purchases based upon National Coal Association figures (12).

Mining method mix was stipulated by application of MESA figures (6).

TABLE 3.1.-6

FATALITY RATES FOR BITUMINOUS COAL MINERS IN THE UNITED STATES AND ORBES STATES

(deaths per million tons mined)

	1972	1973	1974	1975	1976	1977	Mean
SURFACE MINING							
Illinois	0.06	0.10	0.11	0.07	0.00	0.04	0.06
Indiana	0.00	0.04	0.04	0.12	0.04	0.04	0.05
Kentucky	0.06	0.07	0.11	0.17	0.10	0.21	0.12
Ohio	0.16	0.07	0.0	0.03	0.07	0.03	0.06
Pennsylvania	0.00	0.11	0.09	0.16	0.02	0.08	0.08
West Virginia	0.13	0.17	0.05	0.15	0.23	0.05	0.13
ORBES States	0.07	0.09	0.07	0.12	0.07	0.10	0.09
USA	0.08	0.06	0.09	0.10	0.07	0.07	0.08
DEEP MINING							
Illinois	0.29	0.09	0.29	0.19	0.10	0.10	0.18
Indiana	0.74	0.00	0.00	0.00	0.00	0.00	0.12
Kentucky	0.50	0.43	0.29	0.60	0.60	0.50	0.49
Ohio	0.18	0.13	0.34	0.26	0.30	0.21	0.24
Pennsylvania	0.36	0.26	0.33	0.25	0.36	0.21	0.30
West Virginia	0.46	0.38	0.44	0.33	0.29	0.34	0.37
ORBES States	0.41	0.31	0.34	0.36	0.35	0.31	0.35
USA	0.44	0.36	0.36	0.40	0.39	0.35	0.38

SOURCES: References (5), (6), (7), (8), (9), (10).

TABLE 3.1.-7

1975 ACCIDENTAL FATALITY RATES FOR STATES EXPORTING COAL TO ORBES POWER PLANTS

(deaths per million tons mined)

Mining States	Surface Mining	Deep Mining
Virginia	0.10	0.53
Wyoming	0.00	0.00
Montana	0.00	0.00
Maryland	0.49	0.00
Utah	0.00	0.58
Tennessee	0.00	1.40
Colorado	0.21	1.46

Source: Reference (6)

TABLE 3.1.-8

ESTIMATED 1975 ACCIDENTAL MINING FATALITIES ATTRIBUTABLE TO 1975 COAL PURCHASES BY ORBES POWER PLANTS

(number of deaths)

MINING STATES	SURFACE MINING	DEEP MINING	TOTAL
Illinois	0.74	2.31	3.05
Indiana	2.35	0.00	2.35
Kentucky	3.21	11.12	14.33
Ohio	0.42	1.72	2.14
Pennsylvania	1.56	2.88	4.44
West Virginia	0.82	7.91	8.73
Virginia	0.06	0.58	0.64
Wyoming	0.00	0.00	0.00
Montana	0.00	0.00	0.00
Maryland	0.38	0.00	0.38
Utah	0.00	0.29	0.29
Tennessee	0.00	0.08	0.08
Colorado	0.00	0.01	0.01
Total	9.54	26.90	36.44
(Percent)	(26.18)	(73.82)	(100.00)

TABLE 3.1.-9

NON-FATAL DISABLING INJURY RATES FOR BITUMINOUS COAL MINERS IN THE UNITED STATES AND ORBES STATES

(injuries per million tons mined)

	1972	1973	1974	1975	1976	1977	Mean
SURFACE MINING							
Illinois	5.56	6.03	6.44	5.72	6.28	9.27	6.55
Indiana	3.35	2.69	1.80	2.37	3.74	2.69	2.77
Kentucky	5.32	4.87	4.22	6.35	6.77	7.02	5.76
Ohio	2.53	2.60	2.45	2.71	4.23	3.98	3.08
Pennsylvania	7.60	4.77	4.82	5.44	5.80	5.35	5.63
West Virginia	9.75	6.80	7.67	10.18	11.88	14.11	10.07
ORBES States	5.23	4.57	4.41	5.40	6.31	6.61	5.42
USA	5.09	4.27	3.95	5.03	5.47	5.30	4.85
DEEP MINING							
Illinois	23.84	16.29	10.80	16.89	25.89	26.73	20.07
Indiana	39.48	34.70	0.0	27.33	30.12	20.03	25.28
Kentucky	23.65	20.40	20.07	22.52	27.17	26.86	23.44
Ohio	38.25	34.66	21.87	30.25	32.76	49.53	34.55
Pennsylvania	26.17	25.81	21.66	29.66	50.03	60.78	35.69
West Virginia	47.65	43.77	36.79	43.57	54.12	65.07	48.50
ORBES States	34.87	30.80	25.19	31.32	41.62	47.89	35.28
USA	35.87	32.01	25.22	31.11	40.46	45.51	35.01

SOURCES: References (5), (6), (7), (8), (9), (10).

TABLE 3.1.-10

1975 NON-FATAL, ACCIDENTAL INJURY RATES
FOR NON-ORBES STATES SUPPLYING COAL TO
ORBES POWER PLANTS
(injuries per million tons mined)

MINING STATES	SURFACE MINING		DEEP MINING	
	Disabling Injuries	Non-disabling Injuries	Disabling Injuries	Non-disabling Injuries
Virginia	6.17	3.28	38.99	14.15
Wyoming	2.26	3.17	15.56	3.89
Montana	0.81	0.99	0.00	0.00
Maryland	6.92	1.98	46.83	0.00
Utah	0.00	0.00	22.93	20.91
Tennessee	10.94	11.23	18.15	11.87
Colorado	2.78	4.06	14.00	15.75

SOURCE: References (6).

TABLE 3.1.-11

ESTIMATED 1975 NON-FATAL DISABLING INJURIES (BITUMINOUS EXTRACTION) ATTRIBUTABLE TO 1975 COAL PURCHASES BY ORBES POWER PLANTS

(number of injuries)

MINING STATES	SURFACE MINING	DEEP MINING	TOTAL
Illinois	60.17	205.72	265.89
Indiana	46.40	3.83	50.23
Kentucky	119.82	417.30	537.12
Ohio	37.61	199.65	237.26
Pennsylvania	53.20	341.39	394.59
West Virginia	55.79	1043.94	1099.73
Virginia	3.64	42.50	46.14
Wyoming	3.37	0.47	3.84
Montana	1.06	0.00	1.06
Maryland	5.33	1.40	6.73
Utah	0.00	11.47	11.47
Tennessee	0.77	1.09	1.86
Colorado	0.02	0.06	0.08
Total	387.18	2268.82	2656.00
(Percent)	(14.58)	(85.42)	(100.00)

TABLE 3.1.-12

NON-DISABLING INJURY RATES FOR BITUMINOUS COAL MINERS IN THE UNITED STATES AND ORBES STATES

(injuries per million tons mined)

	1972	1973	1974	1975	1976	1977	Mean
SURFACE MINING							
Illinois	13.79	15.55	1.89	1.52	10.71	14.59	9.68
Indiana	11.54	6.78	2.06	2.57	6.55	6.03	5.92
Kentucky	8.98	7.59	5.38	3.90	9.03	7.68	7.09
Ohio	6.72	8.95	4.73	5.17	5.66	5.77	6.17
Pennsylvania	5.07	3.94	3.82	3.67	4.27	3.80	4.10
West Virginia	10.79	8.47	7.61	11.18	9.19	10.61	9.64
ORBES States	9.51	8.52	4.33	4.29	7.52	7.39	6.93
USA	9.02	7.29	3.58	4.14	6.25	5.86	6.02
DEEP MINING							
Illinois	47.88	26.52	7.29	4.94	7.52	5.91	16.68
Indiana	37.99	95.43	0.0	21.86	13.90	0.0	28.20
Kentucky	29.13	22.12	16.63	14.72	23.26	16.03	20.32
Ohio	42.72	29.65	12.90	14.50	12.10	14.74	21.10
Pennsylvania	42.96	37.81	24.45	36.51	53.57	39.14	39.07
West Virginia	55.13	56.21	29.59	41.74	45.99	38.91	44.60
ORBES States	45.62	39.46	21.21	27.39	34.44	26.69	32.47
USA	43.52	37.27	19.88	25.76	32.66	25.76	30.81

SOURCES: References (5), (6), (7), (8), (9), (10).

TABLE 3.1.-13

ESTIMATED 1975 NON-DISABLING INJURIES (BITUMINOUS EXTRACTION) ATTRIBUTABLE TO 1975 COAL PURCHASES BY ORBES POWER PLANTS
(number of injuries)

MINING STATES	SURFACE MINING	DEEP MINING	TOTAL
Illinois	15.99	60.17	76.16
Indiana	50.32	3.06	53.38
Kentucky	73.59	272.76	346.35
Ohio	71.76	95.70	167.46
Pennsylvania	35.89	420.23	456.12
West Virginia	61.27	1000.09	1061.36
Virginia	1.94	15.42	17.36
Wyoming	4.72	0.12	4.84
Montana	1.30	0.00	1.30
Maryland	1.52	0.00	1.52
Utah	0.00	10.46	10.46
Tennessee	0.79	0.71	1.5
Colorado	0.02	0.06	0.08
Total	319.11	1878.78	2197.89
(Percent)	(14.52)	(85.48)	(100.00)

TABLE 3.1.-14

OCCUPATIONAL DISEASE DEATHS AMONG COAL MINERS

Author	Excess Deaths^a Per Person-Yr in Study Population	Range for Use in Post-1970 Populations^b	
		Excess Deaths^a Per Person-Yr	Excess Deaths^a Per 10^6 Tons
Hollingsworth	3.1×10^{-3}	8.9×10^{-4}	0.47
Liddell	4.2×10^{-5} to 1.2×10^{-4}	1.2×10^{-5} to 3.4×10^{-5}	0.01-0.02
Rockette	4.9×10^{-4}	1.4×10^{-4}	0.07

[a] Excess deaths in this table refers to excess deaths per person-year in the coal-miner group studied compared to the control population. Some of the variation among studies is due to the use of different control groups.

[b] After passage of the 1969 Federal Coal Mine Health and Safety Act. Corrected for decreased dust levels.

[c] Using 1900 tons per person-year (1976 estimate).

SOURCE: Reference (13).

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TABLE 3.1.-15

1975 ORBES COAL EXTRACTION HEALTH CASUALTY RATES*

Type of Casualty	Casualty per 1,000 MW_e Power Plant
Accidental Deaths	0.5186
Disabling Injuries	37.80
Non-Disabling Injuries	31.28
Excess Deaths Due to Illness	0.074
Disease Disabilities	4.036

*Based on 70,265 MW_e installed coal-fired electrical generating capacity in 1975. To convert to casualty per 1,000 MW_e-Yr electricity generated, divide the above rates with the average ORBES region loading factor of 0.57.

TABLE 3.1.-16

ORBES PROJECTED COAL FIRED ELECTRICAL GENERATING CAPACITY UNDER EACH SCENARIO

(MWe)

Scenario No.	SCENARIO	1985	2000
1	More Stringent Environmental Regulations	100,870	141,770
2	Business As Usual	100,870	141,770
2a	Export of Electricity	100,870	162,585
2b		100,870	162,435
2c	Nuclear Fuel Emphasis	100,870	100,907
2d	Noncompliance with Air Quality Standards	100,870	142,435
3	Alternative Fuel Emphasis	100,870	122,706
4	Natural Gas Substitution	100,870	102,104
5	Low Economic Growth	100,870	130,761
5a	Very High Economic Growth	100,870	162,243
6	Very Low Energy Growth	100,870	92,945
7	Higher Energy Growth	100,870	167,562

SOURCE: Reference (24)

TABLE 3.1.-17
ESTIMATED HEALTH IMPACTS FROM COAL EXTRACTION, 1985 and 2000

SCENARIO	ACCIDENTAL DEATHS		DISABLING INJURIES		NON-DISABLING INJURIES		DUE TO ILLNESSES			
							EXCESS DEATHS		DISEASE DISABILITIES	
	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000
1 More Stringent Environmental Regulations	53	74	3813	5359	3156	4435	8	11	408	573
2 Business As Usual	53	74	3813	5359	3156	4435	8	11	408	573
2a Export of Electricity	53	85	3813	6146	3156	5086	8	12	408	657
2b	53	85	3813	6140	3156	5081	8	12	408	656
2c Nuclear Fuel Emphasis	53	53	3813	3815	3156	3157	8	8	408	408
2d Non compliance with Air Quality Standards	53	74	3813	5384	3156	4456	8	11	408	575
3 Alternative Fuel Emphasis	53	64	3813	4639	3156	3839	8	10	408	496
4 Natural Gas Emphasis	53	53	3813	3860	3156	3194	8	8	408	413
5 Low Economic Growth	53	68	3813	4943	3156	4091	8	10	408	528
5a Very High Economic Growth	53	85	3813	6133	3156	5075	8	12	408	655
6 Very Low Energy Growth	53	49	3813	3514	3156	2908	8	7	408	376
7 High Energy Growth	53	87	3813	6334	3156	5242	8	13	408	677

Assumptions: Accident and illness rates per unit generating capacity remain constant at 1975 values. Coal sources and extraction technology remain the same. Thermal efficiency i.e. tons coal burned per MWe is constant.

3.2. COAL PROCESSING

A. Introduction and Background Information

Health impacts from processing of coal in the ORBES Region include indirect impacts from the release of toxic trace metals from generated residuals to the water media and organic substances that are potentially mutagenic (consequently carcinogenic), and injuries to cleaning plant operating personnel. The first group of impacts are extremely difficult to predict and quantify due to many site-specific modifying factors. In contrast, accident and injury experience in the coal mining industry have been quantified and published for the past sixty years.

The primary function of coal pretreatment is to supply a feedstock which satisfies the physical and chemical specifications required for the final end-use. Coal preparation (which includes cleaning and processing) is practiced extensively in many coal utilizing industries. Following mining, about 60% of the total coal output of the United States is mechanically cleaned and processed to reduce mineral content and to provide a specified size distribution (1). Approximately 427 million tons of bituminous coal is mechanically cleaned each year before being sent to the industrial and energy market. Of this amount, 80-90% is washed with water (2). Figure 3.2.-1 shows the alternate routes of coal processing and the management of residuals resulting from the operation.

Coal as mined contains a great amount of extraneous rock and other mineral matter. In addition to impurities incorporated in the coal during its deposition, mineral impurities are carried by groundwater into porous layers of fully developed coal seams. Coal seams with larger percentages of impurities produce greater quantities of refuse, which in turn require the use of larger areas for disposal of coal preparation wastes (3). Inorganic matter usually constitutes about 10-20% of raw coal and can be as high as 50%. Economically, it is feasible to remove these impurities from coal because the contaminants dilute the caloric content of coal, produce pollutants when coal is burned, and increase transportation costs on a Btu basis.

Coal processing or cleaning produces wastes which consist of coal fines and rock material. The amount of pollutants generated as a result of coal preparation clearly depends on the quantity of coal processed and its chemical and physical properties (4). According to recent estimates, nearly three billion tons of carbonaceous wastes have accumulated in the United States as a result of coal mining and preparation (5). Some investigators anticipate an increased rate of accumulation of waste due to higher coal production, wider use of indiscriminate mining techniques, improved cleaning methods and greater emphasis on clean fuels. Two examples of this trend is the tenfold increase in the rate at which wastes have been produced since 1940 and the recent estimate that the rate of waste production of 100 million tons per year in 1976 will double by 1980 (5).

B. The Generation of Refuse by Coal Preparation Processes

The cleaning and processing of coal is an important function also because of concern regarding sulfur oxide emissions during the combustion process. The newer preparation plants waste about 10% of the Btu concent of coal while reducing sulfur content to less than 1% (5). In general coal processing involves crushing of coal and separation of heavier mineral matter by various mechanical means using jigs, cyclones, or heavy media baths. Froth flotation and skimming are other preparation methods employed. The reject mineral waste or refuse resulting from coal processing is transported by conveyer or truck to nearby disposal areas. Process water with suspended fines are fed into slurry (tailings) ponds or settling basins. The most widely used washing techniques for coal cleaning (representing 75% of commercial production) utilize density separation methods.

Refuse from coal cleaning is discharged from the preparation plant as a wet aggregate-like material. Cleaning wastes generated at processing operations contain large amounts of removed mineral matter that are usually high in pyritic sulfur which has been removed by the washing process. Residues are composed principally of rock and mineral matter (80% or more), but they also contain a small amount of residual coal. The major mineral constituents of these wastes are clays, quartz, pyrites, and carbonates (5). Table 3.2.-1 tabulates the elemental composition of a West Virginia coal refuse. This rejected material represents (on the average) 20% of the raw coal (6). Significant concentration reductions in trace elements content of coal are achieved by washing the coal. These elements will then be discarded by the washing plant. Coal preparation plant refuse will contain more than 2.5 times the trace element quantities present in the raw coal (5).

Coal and coal wastes contain a broad array of trace or minor elements, including lead, cadmium, arsenic, selenium and mercury. The presence of these elements generates considerable concern because of their toxicity and the low tolerance of plants and animals to them. Evidence is available that many of these trace elements are carried into the environment by water transport (7). Assessment of the hazard associated with such water contamination is needed.

C. Water Contamination From Coal Preparation Refuse

The weathering and leaching of coal preparation refuse can induce several types of water degradation. Environmental impacts are basically in three forms: suspended and settleable solids from erosion and siltation, acid water drainage, and dissolved mineral matter (heavy metals). Approximately 2000 coal preparation waste disposal sites are thought to be contributing to stream or waterway pollution in the United States (5).

Siltation of waterways from coal preparation refuse sites is caused by the settling of finely divided coal, minerals and discarded soil which has been transported by surface water runoff. The degree of erosion (and siltation) is directly influenced by the steepness of exposed and unvegetated slopes, amount of compaction utilized in the site operation, erection of diversion systems and the covermaterial placed over the coal residues (8). It is generally controllable by use of siltation ponds, properly designed diversion ditches for runoff control and energy dissapaters to reduce erosion. Health impacts are not considered to be a consequence of erosion and sedimentation.

Acid water is produced when pyrite or marcasite is exposed to air and water. Sulfur is oxidized and iron is liberated as iron sulfate. Typically, 0.7 to 0.9 kg of acid and 0.2 to 0.3 kg of soluble iron are produced per acre of refuse per day. In some highly mineralized areas, acid has formed at a rate of more than 140 kg per acre per day (5). Acid water drainage from refuse piles varies with location, seam mined, compaction practiced, amount of cover material and extent of revegetation, etc. (8). The acid water formed may be transported off the disposal area by surface water runoff or percolate through the deposited material to dissolve considerable quantities of mineral matter. Occasionally the flow from refuse disposal sites may reach subsurface water systems that are used for potable water supplies.

Because coal refuse is finely divided into small particles with a relatively high exposed surface area, the weathering and leaching processes that produce acid drainage and mineral dissolution can have greater impacts than similar processes in mine discharges (6). In Appalachia, more than 10,000 miles of streams are affected by acid water discharges from coal mines and disposal sites (5). It is estimated that 3.5 million tons of sulfuric acid entered the inland waterways in 1962 from coal related sources (2). About 70% of the acid drainage was attributed to inactive underground mine discharges. Coal preparation plants and refuse areas were responsible for much of the remainder of the acidic effluents (5).

The aqueous drainage from coal refuse usually contains considerable dissolved mineral or inorganic matter (3). Drainage from coal refuse disposal sites typically contains high concentrations of Fe, Al, Ca, Mg, and SO_4 ions which originate from the major minerals in the coal. The highest concentrations of total dissolved species (in the range of 1-5% by weight) are found in the more highly acidic solutions. It has been reported that as little as 400 ppm of Fe or Al ions in soils can result in the mortality of plants, and fish kills may be caused by concentrations of these ions at levels as low as 0.5 ppm (of the more toxic heavy metal ions).

In addition to these well recognized problems, waterborne trace element contaminants are gaining recognition regarding their possible adverse health effects when present in drinking water. Although the concentrations of heavy metals in refuse is low, the large volume of wastes generated provide a source of large quantities of the contaminants which may become available in the food chain.

D. Health Effects of Coal Preparation Residuals in Drinking Water

Possible health problems of the general population associated with coal preparation plants are similar to those expected from coal extraction (toxic heavy metal releases, accidents and injuries). Added acidity (due to the oxidation of sulfur) will increase the solubility of trace metals in the water. Results from the chemical analyses of coal processing residuals indicate high concentrations of iron, aluminum, calcium, manganese and potassium. Consequently, leachate from this residual will contain concentrations of these cations in addition to sulfate anions. Iron (II), manganese and sulfate concentrations often exceed water effluent standards. Of the trace elements normally investigated zinc, chromium and cadmium concentrations exceed various recommended drinking water standards in the leachate.

Nine elements or compounds have been cited most often as water contaminants associated with coal residuals leachate: (1) iron, (2) sulfates, (3) magnesium, (4) manganese, (5) aluminum, (6) calcium, (7) zinc, (8) chromium, and (9) cadmium. Arsenic, vanadium, boron, and barium have also been linked with coal waste discharges.

The major constituents of coal refuse drainage- iron, manganese and sulfates-are not hazardous to man when ingested at concentrations expected to be present in drinking water after dilution with ground or surface waters and processing in a "conventional" water treatment plant. For example, no adverse health effects have been linked with sulfate concentrations below approximately 500 mg/l. Clothes washed in water containing high concentrations of iron and manganese (greater than 0.05 mg/l of Mn) tend to become stained. Also, this water will have a noticeable metallic taste. Due to these attributes, consumption of an aesthetically unacceptable water would be minimal and iron and manganese removal would be required in any treatment process. Manganese toxicity has only been associated with airborne exposure.

Magnesium in water (like manganese) is not considered a public health hazard due to the unpleasant taste which manifests itself before toxic concentrations of the heavy metal ion are reached. The taste threshold for an average person is 500 mg/l while it appears to be 100 mg/l for more sensitive palates. Aluminum and calcium are not toxic at concentrations found in coal residual leachates. These constituents are not considered a health hazard.

Zinc, chromium and cadmium are potentially highly toxic trace elements. There is a wide margin of safety between mean drinking water zinc content and oral doses that will produce toxic effects. Symptoms of zinc poisoning include muscular stiffness and pain, nausea and irritability. An environmental assessment of zinc (soluble) discharges resulting from the leaching of coal preparation plant residuals would seem to indicate that it will not contribute significantly to the daily human load. It is also more likely that households still using lead service pipes and supplied with soft water will contribute more than coal preparation plant leaching to total lead concentrations in tap water. Cadmium can be effectively removed by lime treatment and coagulation with ferric salts. Chromium is poorly removed by conventional water treatment practices. A treatment plant must incorporate reverse osmosis in order to remove sizeable quantities of soluble chromium. Thus, of all trace elements investigated, chromium derived from coal refuse drainage may be present in drinking water at levels exceeding the standards (0.05 mg/l). It is important to note the above concentration is less than the no-observed-adverse-health-effect level and exceeding the standard does not preclude the onset of adverse health effects (such as tubular necrosis of the kidney). However, more studies are needed to determine the potential of low chromium concentrations in drinking water for inducing cancer.

At the present time, there is a complete absence of data regarding low level radioactivity of coal preparation wastes and the presence of organic carcinogens which are found in coal chemicals. It is not possible to make an assessment of health risks of this nature.

E. Potential Health Impacts From Coal Processing - Air Pollution

Expected health impacts from coal processing via inhalation of toxic pollutants would come from fugitive dusts during conveyance and processing of coal. An additional source of particulates is from stack emissions of thermal dryers used in the coal processing plant. Population exposed in the first case is operating personnel and in the latter instance the general public. A comparison of dust levels in the work place would show that cleaning plants are less dusty than underground mines using mechanical miners. Pneumoconiosis records could be misleading due to the industry practice which places miners exhibiting the disease in the coal cleaning plant.

The chemical and physical character of the particulates emitted during the coal preparation operation (particle size range is 1-100 microns) is expected to be similar to the coal itself. Uncontrolled emissions from thermal coal drying units are estimated at 15-25 lbs. of particulates per ton of coal processed. Using a 90% collection efficiency value, particulate emissions amount to 1.5-2.5 lbs/ton processed coal where a cyclone dust collector is utilized (9). Fugitive dust releases (in receiving, stacking and crushing coal) are estimated at 2.4 lbs./ton of coal processes (10). In order to place the emission rates in the proper perspective five 1000 MWe power stations (with electro-static precipitators) would release as much particulate matter as all the thermal drying units in the ORBES region were emitting in 1975. This total is based on a generating capacity (of coal-fired plants) in the ORBES states and an average 98% collection efficiency. Combustion of coal releases almost sixteen times more particulates than the thermal coal drying operations.

The lack of available data does not allow a valid assessment of health impacts expected from coal processing dust releases. Sulfur dioxide concentrations are not expected to be high due to low temperatures used in thermal drying and the sulfur in fugitive dusts is not in the oxidized form. The presence or absence of carcinogenic organic compounds has not been established; however, there should be some concern for this potential health impact as some research has indicated high mutagenic activity (Ames Test) in fractions of airborne particulates collected in urban areas.(11)

F. Coal Processing Accidents and Injuries: Background Information

Although coal workers are aggregated with preparation plant personnel in the statistics of accident and injury experience in coal mining, most of the available data will allow disassociation of coal workers for analysis. Although underground miners face the highest risks as noted in the previous section, cleaning plant personnel face the same hazards as those present in stone and lime processing, metallic ore separation plants and similar industrial activities. Major characteristics of the coal preparation process are materials handling and automated separation. Hazards faced by the worker are those resulting from unsafe work practices and equipment failure. Chronic health impacts are associated with dust, noise and some toxic agents.

Processing (mainly coal cleaning to remove refuse, tramp iron and pyrites) may be carried out in conjunction with extraction at the mine site, at a remote location which handles the output of several mines, or at the power plant (mine-mouth or remote) itself. Some processing at the power plant (i.e. additional cleaning, grinding, crushing or pulverizing and drying) is accomplished prior to conveyence to the burners for combustion. All of the above unit operations are carried out through the use of automated equipment making the process one of low labor intensity. Some coal cleaning plants are completely automated through the efficient utilization of enclosed conveyers (dust-proof and noise insulated) and inside buildings which are totally devoid of windows. The only access provided to personnel is for maintenance purposes. Other coal cleaning plants (located in more remote settings) may be completely open (without sides) with consequent lowering of dust concentrations and noise at the workplace. Also, the number of workers in the coal cleaning plant actually operating machinery or controlling the production process may range from zero to 250 depending on the degree of automation, which in turn is dictated by end-use requirements of the clean coal, the coal's economic value and the ultimate destination (transportation costs).

Steam coal, as it is classified by the coal industry, which is used for power generation (both commercial and industrial) does not require the degree of cleaning called for in steel coking operations. In addition, economic value of metallurgical coal ranges from two to three times that of the fossil fuel destined to be consumed in generating electricity. Consequently, the degree of treatment in coal cleaning is lower, but conversely the use of personnel protection measures (dust control and noise suppression) are also lower. Preparation plant workers processing steam coal will be protected only to the degree required by statutes, level of activity by the cognizant enforcement agency and financial resources of the plant owners.

G. Coal Processing in the ORBES Region

The Minerals Yearbook (23) published annually by the U.S. Department of Interior reports on bituminous coal productivity by region and state. It also tabulates the quantities of coal that are processed in the individual states. Table 3.2.-2 extracted from the yearbook tabulates bituminous coal production in each of the states in the ORBES region. It also includes the quantities of mechanically cleaned coal (at the mines) handled in the base year 1975.

Approximately half (48.6%) of the coal produced in the region is mechanically cleaned. It is interesting to note the levels of cleaning in Illinois and Indiana are above 75%. The highest tonnage rate of coal cleaning occurred in West Virginia and may be attributed to the large reserves of metallurgical coal and great amount of the fuel which is exported abroad.

Only 5.8% of coal cleaned in the ORBES states is thermally dried. (See Table 3.2.-3 for the breakdown of quantities.) This would seem to indicate that the contribution of air pollutants due to coal processing might be negligible when compared to the particulates attributed to combustion of fossil fuel. Most of the thermally dried coal was processed in West Virginia, possibly due to the exported volumes and the long transportation distances involved. High moisture coal may be a characteristic of the area.

Almost 90% (89.5%) of the coal mined in the ORBES region is processed in some way which generates refuse either at the mine site or coal cleaning plant location (if it is remote from the mine). The tonnages that are not processed are tabulated by each ORBES state in Table 3.2.-4.

In summary: half of the bituminous coal produced in the ORBES region is cleaned mechanically; 90% is crushed, screened or cleaned; and only 6% is thermally dried (this is probably a function of moisture content of the coal, its end-use and transportation distances involved).

H. Injury Experience in Coal Preparation

Kogut and Llewellyn (13) completed a comprehensive analysis of accident and fatality statistics for the coal mining industry based on work location. Tables 3.2.-5 and 3.2.-6 show the number of fatalities, injuries and average employment in the coal mining industry for the years 1972-1975. Table 3.2.-5 is for surface and Table 3.2.-6 is for underground occupations. The accident and fatality rates are per million man-hours.

Any discrepancies between the figures listed in Tables 5 and 6 and those which follow may be due to different job classifications. Job titles were taken from dust sampling records, but the actual accidents and fatalities (although they may have occurred in the coal cleaning plant) may have been attributed to mechanics, electricians or some other job classification. Almost all of the fatalities reported in coal cleaning plants during 1972-1975 were caused by haulage, machinery or electrical accidents.

Coal cleaning plant operators suffered no fatalities during that reporting period. The nonfatal accident rate was 425 disabling and non-disabling injuried per million man-hours worked. Ranking of the cleaning plant operators when compared to 39 other occupational classes in both underground and surface groups is the sixth safest job category. This is for nonfatal injuries as the stochastic nature of fatal accidents coupled with very low numbers of occurrence is not a good measure of hazard. A cleaning plant operator occupied the fourth safest job in the surface occupation group among 17 work classes. Only two jobs (in underground occupations) were safer than the coal preparation plant operator during that time period.

> "To establish that one occupation is more hazardous than another, a simple comparison of fatality or injury totals is not sufficient. One occupation may have experienced twice the injuries of another, but if it employs 10 times the number of workers, then its injury record is 5 times the better of the two. Information on injury occurrence must be combined with information on employment within each occupational category. This is done by expressing the injury record as a rate: the number of injuries reported for the occupation per million man-hours worked in the occupation." (13)

I. Coal Cleaning Injury Experience in the ORBES Region

In general, the injury experience reported for coal cleaned by mechanical coal cleaning plants in the sites comprising the ORBES Region is higher than plants reported on a national basis. All of the fatalities reported in 1974 and 1976 at mechanical coal cleaning plants occurred in the study area. Disabling injuries included in the statistics were reported mainly in ORBES plants. Table 3.2.-7 shows a breakdown of fatalities, disabling accidents and severity rates of all disabling accidents which took place in coal cleaning plants in each of the ORBES states during 1972-1977. Three states -Kentucky, Pennsylvania and West Virginia- consistently accounted for almost all fatalities and a major share of disabling injuries in the study area.

Major categories (or classifications) of causes of the accidents and fatalities in all coal cleaning plants appear to be: slips or falls of persons, handling materials, and machinery involvement. Table 3.2.-8 includes a division of disabling injuries by causative category (14 classes) for each of the ORBES states during 1972-1977. Reasons for the good showing of Illinois, Indiana and Ohio are not clearly evident. Part of the explanation may be level of operation-production totals. Although coal cleaning is practiced on a high percentage of raw coal produced in each of the above states, total tonnage is higher in the other states. However, injury and fatality rates (per million man-hours worked) are still higher in Kentucky, Pennsylvania and West Virginia. Age of the plant and size of operation may have some correlation with the injury rates.

Table 3.2.-9 includes the statistics covering fatalities and disabling injuries at coal cleaning plants in the study area as a whole. Fatality and disabling injury rates (per million man-hours worked) are calculated for four occupational locales: (1) underground mines-underground occupations; (2) underground mines-surface occupations; (3) strip mines; and (4) coal cleaning plants. It is interesting to note that coal cleaning generated higher accident rates than strip mining but lower frequencies than deep mining or associated surface occupations.

J. Development of Baseline Data for the ORBES Region

In order to develop baseline data for determining health impacts of coal cleaning in the ORBES region, fatality and disabling injury rates per million tons of coal cleaned are necessary. The data published by MESA does not include production figures for mechanical coal cleaning plants. The Mineral Yearbook data regarding coal cleaning does include tonnages of raw coal, cleaned coal and coal refuse. We have used the amount of coal cleaned to develop injury rates. Table 3.2.-10 lists data for each of the ORBES states in the years 1972-1977. Although we have not included amounts of coal originating in non-ORBES states, fatality and injury rates, where relevant, were calculated in the same manner. The calculated rates are used to determine the number of fatalities and disabling injuries to be assigned to the ORBES region on an individual state basis and for the study area as a whole.

Talbe 3.2.-11 provides data resulting from calculations using coal consumption figures for individual coal-fired power plants in the ORBES Region. Plant values were aggregated by state from a reference (12) which lists individual plants to be included or excluded from the study. Consumption volumes were used to determine values. Coal supplies from outside the study area were calculated on a prorated basis from 1975 published figures (23). 1975 coal orders were multiplied by the ratio of 1974/1975 power plant consumption values to provide a more reasonable approximation based on the actual volumes. Similar data was developed for 1972 and 1973 power plant factors. We feel that this would more accurately reflect actual values due to the pronounced trend of increasing usage of western coal at certain power plants in the ORBES region. We assume that western coal was burned in order to comply with sulfur dioxide emission standards at these plants. In addition, most of the western strip mines were coming online during 1972-73. Actual data as reported in the steam plant factors were used for calculating for 1975 to 1977.

In order to determine the quantities of cleaned coal burned at the power plants, we made the assumption that all coal shipped to mine-mouth generating stations would not be mechanically cleaned. In addition, almost all mine-mouth power plants (in the ORBES states) are in the study area. All anthracite coal was excluded from the study figures. All other coals shipped to the included power plants are assumed to be cleaned at mechanical coal cleaning plants, except for some western coal for which the total cleaned coal reported is less than the amount ordered by ORBES power stations. All Montana coal was assumed to be non-processed fuel because there are no coal cleaning plants in that state.

Calculations to determine fatalities and injuries assignable to the study area utilized the aforementioned rates. Overall for the years 1972-1976, 13.5 fatalities and 988.1 disabling injuries were attributable to coal cleaning operations in the ORBES area. Use of a linear regression analysis to predict future fatalities and injuries is questionable due to the short time period included. The average annual coal preparation accidental injuries and fatalities in the ORBES Region for the five years (1972-1976) was 2.7 deaths and 197.6 disabling injuries.

For the year 1975, 7 fatalities, 482 disabling injuries, and 827 non-disabling injuries were reported at all of the coal cleaning plants in the states that supplied steam coal to the ORBES region power plants (17). On the basis of coal consumed (by origin of the fuel) at the power stations, 4.252 of the fatalities, 233.737 of the disabling injuries, and 365 of the non-disabling injuries are attributed to coal used for power generation in the ORBES region.

K. Health Impact Projections for the ORBES Scenarios

Using the baseline data developed in the previous section, health damage attributable to coal processing can be calculated for the years 1985 and 2000. In order to make the estimates, certain assumptions were made. These were: no change in coal processing technology or source of the fuel, constant thermal efficiency at the ORBES power plants, and constant accident and illness rates using 1975 as the base year. Thus, from the 1975 health damage data (accidental deaths, disabling and non-disabling injuries) the rates per 1000 MWe generating capacity were calculated. This information is presented in Table 3.2.-12. Health damage due to illness could not be included because this information is not presented separately in statistics of coal processing and extraction.

Then, using the projected installed generating capacity (Table 3.1.-16), the health damage for the various scenarios was estimated. The results are presented in Table 3.2.-13. In 1985, health impacts will be the same for all scenarios as the estimated installed generation capacity is identical for all of the scenarios: 6 accidental deaths, 326 disabling injuries and 725 non-disabling injuries can be attributed to coal cleaning for ORBES power plants in 1985.

For the year 2000, the health impacts will range from a low for Scenario 6 (very low energy growth) to a high for Scenario 7 (high energy growth). The range of the estimated impacts are: 6 to 10 accidental deaths, 309 to 557 disabling injuries, and 668 to 1204 non-disabling injuries.

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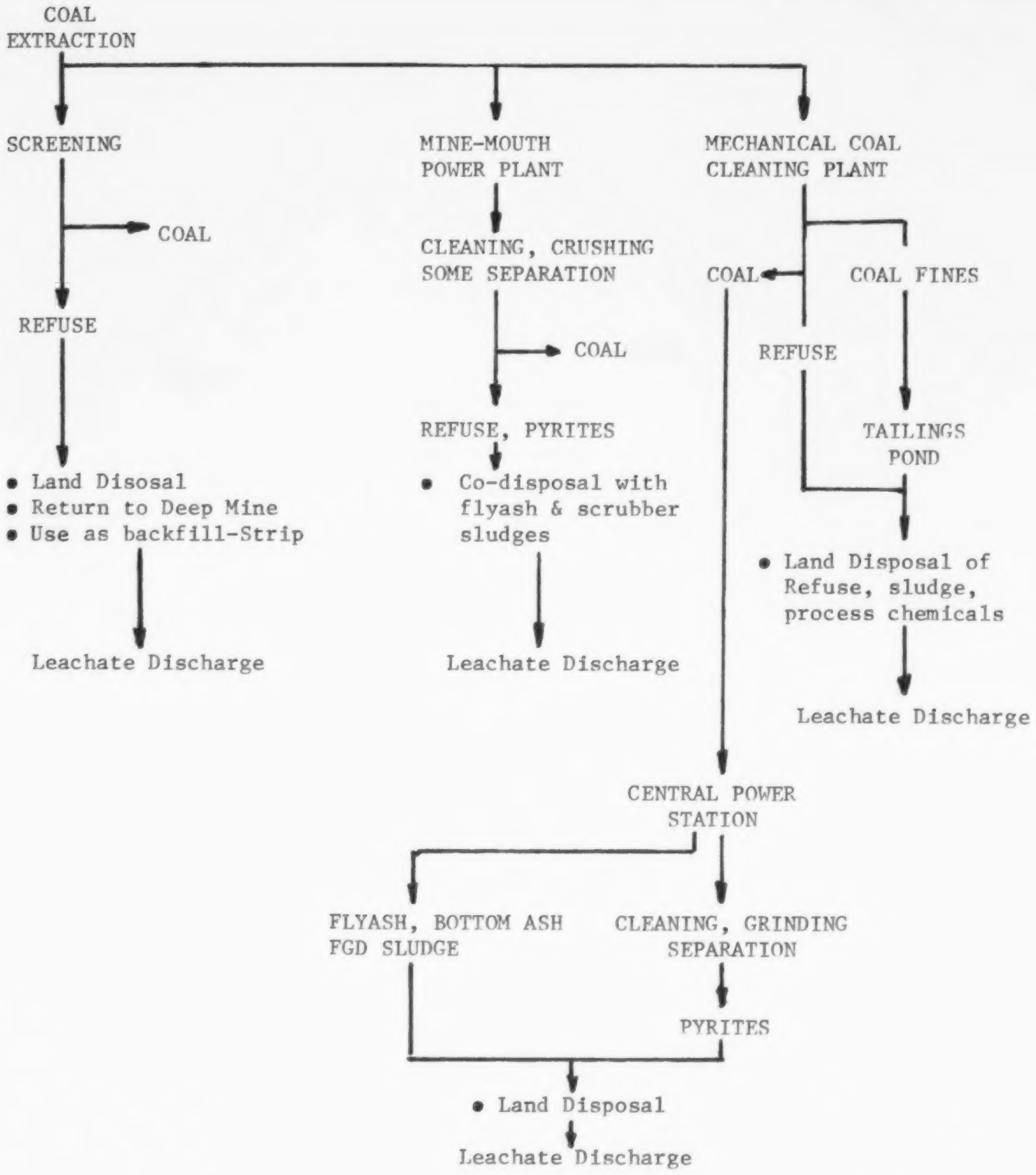
FIGURE 3.2.-1

COAL PROCESSING ROUTES AND RESIDUALS FROM POWER GENERATION



COAL EXTRACTION
SCREENING
COAL
REFUSE
• Land Disosal
• Return to Deep Mine
• Use as backfill-Strip
Leachate Discharge
MINE-MOUTH POWER PLANT
CLEANING, CRUSHING SOME SEPARATION
COAL
REFUSE, PYRITES
• Co-disposal with flyash & scrubber sludges
Leachate Discharge
MECHANICAL COAL CLEANING PLANT
COAL
COAL FINES
REFUSE
TAILINGS POND
• Land Disposal of Refuse, sludge, process chemicals
Leachate Discharge
CENTRAL POWER STATION
FLYASH, BOTTOM ASH FGD SLUDGE
CLEANING, GRINDING SEPARATION
PYRITES
• Land Disposal
Leachate Discharge

TABLE 3.2.-1

ELEMENTAL ANALYSIS OF WEST VIRGINIA COAL REFUSE*

Element	Min. Value	Max. Value
Be	0.2	3
Na	150	375
Mg	500	8000
Al(%)	2.5	---
Si(%)	2.5	---
K	500	1200
Ca	50	2000
Sc	3	25
Ti	300	3000
V	25	250
Cr	3	25
Mn	65	1300
Fe(%)	0.75	4.1
Co	3	25
Ni	25	250
Cu	12	50
Zn	30	85
Ga	3	25
Y	3	25
Zr	3	25
Ag	0.3	2.5
Cd	0.25	1.0
Pb	20	150

*All values ppm unless otherwise indicated.
SOURCE: Bush, et al., 1974 as cited in Wewerka, et al., 1976 (5).

TABLE 3.2.-2

MECHANICAL CLEANING AT BITUMINOUS COAL MINE IN THE ORBES STATES IN 1975

STATE	TOTAL PRODUCTION (1000 Sht. Tons)	MECHANICALLY CLEANED (1000 Sht. Tons)	% CLEANED (Percent)
Illinois	59537	45120	76
Indiana	25124	19402	77
Kentucky	143613	43578	30.3
Ohio	46770	14108	30
Pennsylvania	84137	42512	50.5
West Virginia	109283	63139	58
TOTAL	468464	227859	48.6

SOURCE: Reference (23)

TABLE 3.2.-3

MECHANICALLY CLEANED COAL THAT WAS THERMALLY DRIED IN THE ORBES STATES IN 1975

STATE	TOTAL PRODUCTION (1000 Sht. Tons)	THERMALLY DRIED (1000 Sht.Tons)	% THERMALLY DRIED (Percent)
Illinois	59537	3220	5.4
Indiana	25124	-	-
Kentucky	143613	2219	1.5
Ohio	46770	605	1.3
Pennsylvania	84137	4815	5.7
West Virginia	109283	16117	14.7
TOTAL	468464	26976	5.8

SOURCE: Reference (23)

TABLE 3.2.-4

EXTENT OF COAL PROCESSING* IN THE ORBES STATES

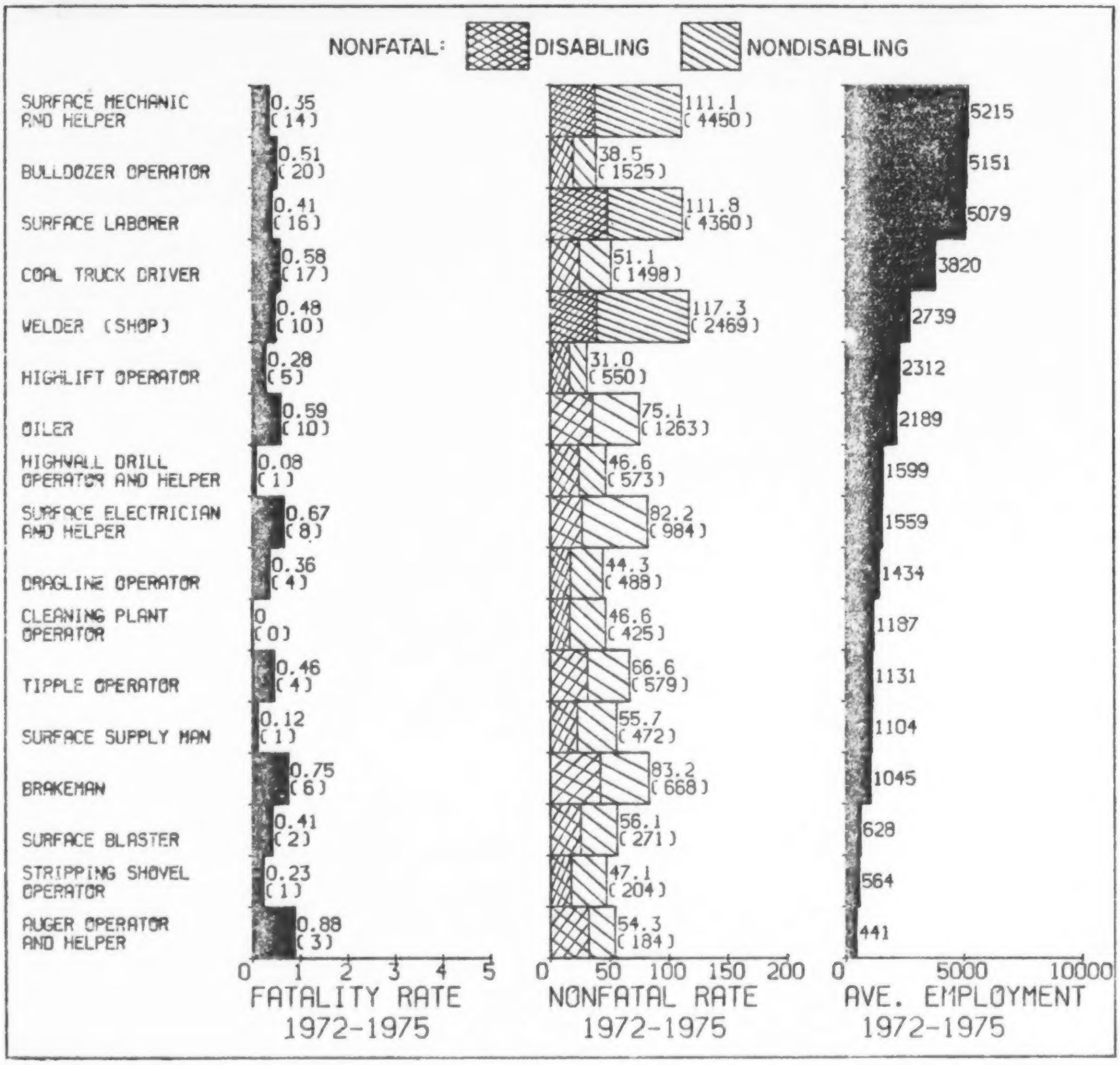
STATE	TOTAL PRODUCTION (1000 Sht. Tons)	NO PROCESSING (1000 Sht. Tons)	PROCESSED (Percent)
Illinois	59537	1460	97.5
Indiana	25124	297	99.0
Kentucky	143613	23005	84.0
Ohio	46770	6931	85.0
Pennsylvania	84137	11971	85.0
West Virginia	109283	5516	95.0
TOTAL	468464	49180	89.5

* Processing includes: mechanical cleaning, crushed or screened

SOURCE: Reference (23)

TABLE 3.2.-5

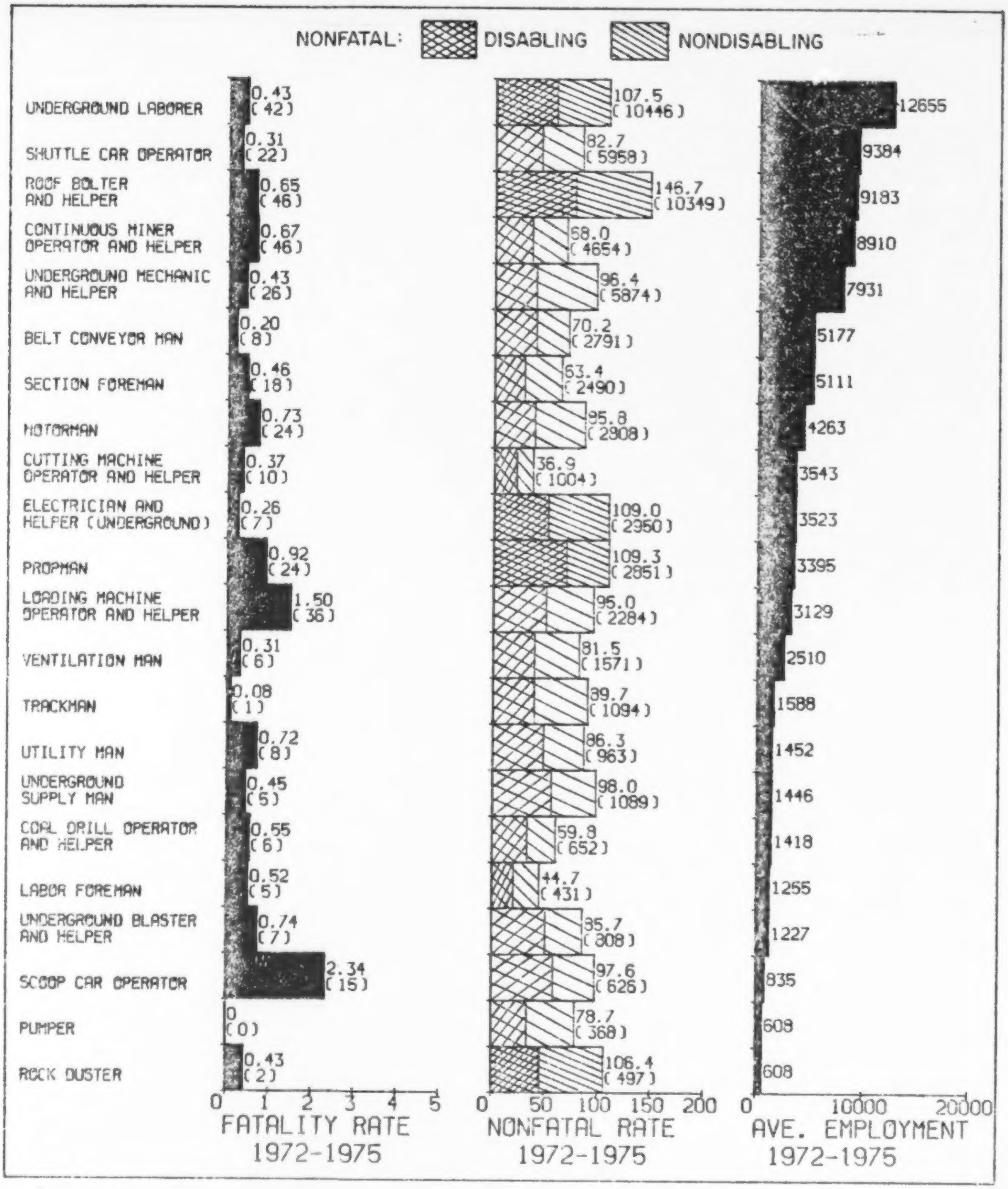
INJURY RATES AND EMPLOYMENT FOR COAL SURFACE OCCUPATION, 1972-1975 PER MILLION MAN-HOURS WORKED



SOURCE: Reference (13)

TABLE 3.2.-6

INJURY RATES AND EMPLOYMENT FOR COAL UNDERGROUND OCCUPATIONS, 1972-1975 PER MILLION MAN-HOURS WORKED



SOURCE: Reference (13)

TABLE 3.2.-7

NUMBER OF FATALITIES, DISABLING ACCIDENTS AND SEVERITY RATES OF DISABLING INJURIES AT MECHANICAL COAL CLEANING PLANTS IN THE ORBES REGION

Year	State	NUMBER OF DISABL. ACCIDENTS		SEVERITITY RATES ALL DISABLING (per Mman-hours)
		FATAL	ALL DISABLING	
1972	Illinois	-	32	421
	Indiana	-	5	94
	Kentucky	2	53	4351
	Ohio	-	9	273
	Pennsylvania	2	51	3834
	West Virginia	1	221	1773
	All Mining	146	11671	5683
1973	Illinois	-	43	623
	Indiana	-	8	206
	Kentucky	1	86	2448
	Ohio	-	34	445
	Pennsylvania	2	48	3841
	West Virginia	2	263	3630
	All Mining	121	10388	5026
1974	Illinois	-	17	577
	Indiana	-	2	27
	Kentucky	2	92	5369
	Ohio	-	10	400
	Pennsylvania	2	52	4061
	West Virginia	6	195	6101
	All Mining	121	7938	4797

Year	State	NUMBER OF DISABL. ACCIDENTS		SEVERITY RATES ALL DISABLING (per Mman-hours)
		FATAL	ALL DISABLING	
1975	Illinois	-	22	642
	Indiana	-	6	246
	Kentucky	3	105	5292
	Ohio	1	18	4297
	Pa.	-	53	541
	W. Va.	3	220	2818
	All Mining	34	1684	3024
1976	Illinois	-	39	611
	Indiana	-	1	158
	Kentucky	2	127	4592
	Ohio	-	21	522
	Pa.	2	120	3273
	W. Va.	3	294	3698
	All Mining	133	13460	4016
1977	Illinois	-	54	1309
	Indiana	-	1	106
	Kentucky	-	133	1432
	Ohio	-	24	989
	Pa.	1	109	2557
	W.Va.	3	350	5427
	All Mining	119	13950	5071

SOURCE: References (14), (15), (16), (17), (18), (19)

TABLE 3.2.-8

NUMBER OF DISABLING INJURIES IN COAL CLEANING PLANTS IN ORBES STATES, 1972-77

		SLIDING OR FALLING MATERIAL OR OBJECTS	SLIPS OR FALLS OF PERSONS	HANDLING MATERIAL	HANDTOOLS	SLIPPING OR KNEELING ON SHARP OR LOOSE OBJECTS	STRIKING OR BUMPING AGAINST OBJECTS	HAULAGE	EXPLOSIONS OF GAS OR DUST	EXPLOSIVES	ELECTRICITY	MACHINERY	SUFFOCATION (NO FLAME OR SMOLDERING)	FIRES OR SUFFOCATION FROM FIRES	MISC. CAUSES	TOTAL
ILLINOIS	1972	-	7	10	2	-	-	1	-	-	2	6	-	-	5	33
	1973	1	13	15	-	2	-	4	-	-	1	3	-	-	4	43
	1974	-	3	5	2	-	-	1	-	-	1	3	-	-	2	17
	1975	-	6	6	1	2	2	-	-	-	1	3	-	-	1	22
	1976	1	12	13	3	-	1	-	-	-	-	2	-	-	7	39
	1977	2	18	23	3	1	-	1	-	-	-	1	-	-	4	54
Total		5	59	72	11	5	3	7	-	-	5	18	-	-	23	208
Indiana	1972	-	-	1	2	-	-	-	-	-	-	1	-	-	1	5
	1973	-	3	1	1	-	-	-	-	-	1	1	-	-	1	8
	1974	-	-	1	-	-	-	-	-	-	-	1	-	-	-	2
	1975	-	1	3	-	-	1	-	-	-	-	-	-	-	1	6
	1976	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
	1977	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Total		-	6	6	3	-	1	-	-	-	1	3	-	-	3	23
Kentucky	1972	3	7	12	4	1	-	10(1)	-	-	3 (1)	6	-	-	5	51
	1973	3	17	27	7	3	1	13	-	-	3	7(1)	-	1	3	85
	1974	-	16(1)	18	3	4	-	22	2	-	4	9(1)	-	-	12	90
	1975	4	24(1)	26	9	2	1	6(1)	1	(1)	-	16	-	-	13	102
	1976	3	26	29	10	1	2	19(1)	-	-	2	21(1)	-	2	10	125
	1977	7	28	33	13	1	2	20	-	-	4	12	-	-	13	133
Total		20	118	145	46	12	6	90	3	-	16	71	-	3	56	586
Ohio	1972	-	6	3	-	-	-	-	-	-	-	-	-	-	-	9
	1973	1	13	10	1	-	-	5	-	-	-	3	-	-	1	34
	1974	1	2	5	-	-	-	1	-	-	-	1	-	-	-	10
	1975	-	4	4	1	-	1	1	-	-	-	4(1)	-	-	2	17
	1976	-	10	3	-	1	2	2	-	-	-	1	-	-	2	21
	1977	-	11	5	1	-	-	2	-	-	-	3	-	-	2	24
Total		2	46	30	3	1	3	11	-	-	-	12	-	-	7	114
Penna.	1972	-	9	12	3	1	1	4(1)	-	-	5	7(1)	-	1	6	49
	1973	4	17	13	1	-	-	3(1)	-	-	-	5(1)	-	-	3	46
	1974	2(1)	5(1)	10	4	1	-	17	-	-	1	7	-	-	3	50
	1975	2	17	15	5	1	2	7	-	-	-	2	-	-	2	53
	1976	3(1)	33	38	10	3	3	9(1)	-	-	1	8	-	-	10	118
	1977	-	31	46	5	1	-	6	-	-	2	9(1)	-	-	8	108
Total		11	112	134	28	7	6	30	-	-	9	38	-	1	32	424
W. Va.	1972	7	45	68	15	6	1	43	1	-	2	15(1)	1	1	15	220
	1973	11	37	69	30	7	1	46(1)	-	-	5(1)	23	-	1	31	261
	1974	6(2)	31	51	16	5	3	41(1)	-	-	6(1)	13(2)	-	-	17	189
	1975	6	36	84	20	2	2	26(1)	1	1	6(2)	12	1	1	19	217
	1976	11(1)	72	77	23	10	3	46	-	-	4(1)	26(1)	-	1	18	291
	1977	10(1)	88	127	23	8	1	43(2)	-	-	5	22	-	2	18	347
Total		51	309	476	127	38	11	245	2	1	28	111	2	6	118	1525
GRAND TOTAL		89	650	863	218	63	30	383	5	1	59	253	2	10	239	2850

( ) numbers in parentheses indicate fatalities

SOURCE: References (14), (15), (16), (17), (18), (19)

TABLE 3.2.-9

FATALITIES, DISABLING INJURIES AND FATALITY AND DISABLING INJURY RATES IN ORBES REGION 1972-1977

Year	MILLION MAN-HOURS WORKED			
	UNDERGROUND MINES		Strip Mining	Cleaning Plants
	Undgrd	Surface		
1972	142.880	14.123	37.724	17.089
1973	142.882	13.296	40.498	18.696
1974	143.883	14.904	52.092	19.352
1975	175.051	19.078	66.414	23.125
1976	179.807	19.351	70.245	23.734
1977	169.067	19.142	77.482	26.051
TOTAL	953.57	100.524	344.456	128.047

Year	NUMBER OF FATALITIES				NUMBER OF DISABLING INJURIES			
	UNDGRD. MINES		Strip Mines	Clean. Plants	UNDGRD. MINES		Strip Mines	Clean. Plants
	Undgrd	Surf.			Undgrd.	Surf.		
1972	95	5	11	5	8104	457	856	367
1973	74	3	15	5	7221	310	778	477
1974	72	4	13	10	5350	291	819	358
1975	77	8	22	7	7011	406	1056	417
1976	78	5	14	7	9139	649	1293	595
1977	58	8	21	4	9465	617	1473	667
TOTAL	454	33	96	38	46290	2730	6275	2881

Year	FATALITY RATE ($/10^6$ man-hrs.)				DISABLING INJ. RATE ($/10^6$ man-hrs.)			
	UNDGRD. MINES		Strip Mines	Clean. Plants	UNDGRD. MINES		Strip Mines	Clean. Plants
	Undgrd	Surf.			Undgrd.	Surf.		
1972	.664	.354	.291	.282	56.72	32.36	22.69	21.47
1973	.518	.215	.370	.267	50.54	22.26	19.21	25.51
1974	.500	.268	.250	.516	37.18	19.52	15.72	18.50
1975	.440	.419	.331	.303	40.05	21.28	15.90	18.03
1976	.434	.258	.199	.295	50.82	33.54	18.40	25.06
1977	.343	.418	.271	.153	55.98	32.23	19.01	25.60
TOTAL	.476	.328	.279	.297	48.54	27.16	18.21	22.50

SOURCE: References (14), (15), (16), (17), (18), (19)

TABLE 3.2.-10

COAL CLEANING TONNAGES, WORKTIME, PRODUCTIVITY RATES AND FATALITY AND DISABLING INJURY RATES DUE TO COAL CLEANING IN THE ORBES STATES 1972-1977

STATE	CLEANED COAL** (1000 tons)	WORKTIME CLEANING * (man-hours)	PRODUCTIVITY RATE (tons/man-hr)	COAL CLEANING* fatalities	FATALITY RATE (fat./10^6 tons)	COAL CLEANING * disabl. injury	DISABLING INJURY RATE (inj/10^6 tons)
1972							
Illinois	48837	2 017 103	24.2	–	–	33	.675
Indiana	19577	491 123	39.8	–	–	5	.255
Kentucky	38608	3 102 932	12.44	2	.052	51	1.320
Ohio	14163	882 817	16.04	–	–	9	.635
Penna.	45612	3 507 937	13.0	2	.044	49	1.074
W. Va.	83325	7 087 229	11.76	1	.012	220	2.640
TOTAL	250122	17 089 341	14.64	5	.020	367	1.467
1973							
Illinois	48091	2 182 779	22.03	–	–	43	.894
Indiana	19699	557 936	35.3	–	–	8	.406
Kentucky	42269	3 488 298	12.12	1	.024	85	2.011
Ohio	14588	1 748 977	8.34	–	–	34	2.331
Penna.	45731	3 730 049	12.26	2	.044	46	1.006
W. Va.	75672	6 988 013	10.82	2	.026	261	3.449
TOTAL	246050	18 696 052	13.16	5	.020	477	1.939
1974							
Illinois	45313	2 004 901	22.6	–	–	17	.375
Indiana	19097	514 905	37.08	–	–	2	.105
Kentucky	43628	4 457 863	9.79	2	.046	90	2.063
Ohio	13617	1 416 232	9.61	–	–	10	.734
Penna.	41302	3 717 117	11.11	2	.048	50	1.211
W. Va.	62833	7 241 020	8.60	6	.095	189	3.008
TOTAL	225790	19 352 038	11.66	10	.044	358	1.586
1975							
Illinois	45120	2 048 846	22.02	–	–	22	.488
Indiana	19402	540 703	35.88	–	–	6	.309
Kentucky	43578	5 269 337	8.27	3	.069	102	2.341
Ohio	14108	1 571 630	8.97	1	.071	17	1.205
Penna.	42572	4 465 942	9.53	–	–	118	2.772
W. Va.	63139	9 228 323	6.84	3	.048	217	3.437
TOTAL	227919	23 124 781	9.85	7	.031	482	2.115
1976							
Illinois	44525	2 229 651	19.97	–	–	39	.876
Indiana	19830	526 825	37.64	–	–	1	.050
Kentucky	43073	4 988 134	8.64	2	.046	125	2.900
Ohio	14827	1 676 505	8.29	–	–	21	1.420
Penna.	43197	5 209 879	8.29	–	–	118	2.730
W. Va.	64421	9 103 085	7.08	3	.046	291	4.520
TOTAL	229873	23 734 079	9.68	5	.022	595	2.590
1977							
Illinois		2 329 036		–	–	54	
Indiana		537 572		–	–	1	
Kentucky		6 582 524		–	–	133	
Ohio		1 682 179		–	–	24	
Penna.		5 821 008		1		108	
W. Va.		9 098 782		3		347	
TOTAL				4		667	

* SOURCE: References (14)-(19)

** SOURCE: References (20)-(25)

TABLE 3.2.-11

COAL CONSUMED, ESTIMATED CLEANED COAL AND FATALITIES AND DISABLING INJURIES ASSIGNED TO ORBES REGION POWER PLANTS

STATE	COAL CONSUMED* (1000 tons)	SHIPPED TO MINE MOUTH POWER PLANT+ (1000 tons)	CLEANED COAL (1000 tons)	FATALITY RATE (/10^6 tons)	ORBES FATALITIES	DISABLING INJURY RATE (/10^6 tons)	ORBES DISABLING INJURIES
				1972			
Illinois	19612.1	5642	13970.1	-	-	0.675	9.43
Indiana	15293.4	2374	12919.4	-	-	0.255	3.29
Kentucky	31900.8	8917	22983.8	.052	1.195	1.320	30.34
Ohio	17996.9	5667	12329.9	-	-	0.635	7.83
Penna.	21094.1	8091	13003.1	.044	0.572	1.074	7.44
W. Va.	23050.0	5361	17689.0	.012	0.212	2.640	46.70
Sub-total					1.979		105.03
Montana	1761.4	-	-	-	-	-	-
Wyoming	1360.7	-	225.0	-	-	8.88	2.00
Colorado	-	-	-	-	-	-	-
Utah	416.9	-	-	-	-	-	-
Tenn.	87.4	-	87.4	-	-	1.20	0.50
Alabama	-	-	-	-	-	-	-
Virginia	850	-	850.0	.113	.096	2.42	2.057
Maryland	580.4	-	-	-	-	-	-
TOTAL					2.075		109.797
				1973			
Illinois	17672.2	4399	13273.2	-	-	0.894	11.866
Indiana	17202.8	411	16791.8	-	-	0.406	6.817
Kentucky	33539.1	8707	24832.1	.024	.596	2.011	49.937
Ohio	19332.1	5343	13989.1	-	-	2.331	32.609
Penna.	22396.6	7246	15150.6	.044	.666	1.006	15.241
W. Va.	26371.2	6188	20183.2	.026	.026	3.449	69.611
Sub-total					1.786		186.081
Montana	1071	-	-	-	-	-	-
Wyoming	1425.2	-	221.1	-	-	4.525	1.0
Colorado	-	-	-	-	-	-	-
Utah	454.4	-	454.4	-	-	3.0	1.36
Tenn.	89.3	-	89.3	-	-	1.596	.142
Alabama	-	-	-	-	-	-	-
Virginia	929.9	-	929.9	.056	.055	1.970	1.95
Maryland	678.3	-	70.7	-	-	-	-
TOTAL					1.841		190.533
				1974			
Illinois	20204.5	6560	13644.5	-	-	.375	5.116
Indiana	16277.9	299	15978.9	-	-	.105	1.678
Kentucky	33921.8	6851	27070,8	.046	.923	2.063	55.845
Ohio	19729.8	5285	14444.8	-	-	.734	10.602
Penna.	18805.9	6479	12326.9	.048	.592	1.211	14.928
W. Va.	28180.7	5695	22485.7	.095	2.136	3.008	67.637
Sub-total					3.651		155.806
Montana	1217.1	-	-	-	-	-	-
Wyoming	1462.1	-	455.0	-	-	-	-
Colorado	11.2	-	-	-	-	-	-
Utah	462.8	-	462.8	-	-	0.771	.329
Tenn.	90.6	-	90.6	-	-	0.500	.045
Alabama	-	-	-	-	-	-	-
Virginia	1119.8	-	1119.8	-	-	0.709	.794
Maryland	767.7	-	145.9	-	-	-	-
TOTAL					3.651		156.974

* SOURCE: References (26), (27), (28) and prorated on the 1975 distribution of purchases listed in Ref. (29).

+ SOURCE: References (20)-(25).

ORBES power plants listed in Reference (12).

TABLE 3.2.-11 (Continued)

STATE	COAL CONSUMED* (1000 tons)	SHIPPED TO MINE-MOUTH POWER PLANTS+ (1000 tons)	CLEANED COAL (1000 tons)	FATALITY RATE (/10^6 tons)	ORBES FATALITIES	DISABLING INJURY RATE (/10^6 tons)	ORBES DISABLING INJURIES
				1975			
Illinois	21871.3	7062	14809.3	-	-	0.488	7.226
Indiana	18653.5	1	18652.5	-	-	0.309	5.764
Kentucky	37665.2	8718	28947.2	.069	1.997	2.341	67.765
Ohio	20868.3	5683	15185.3	.071	1.078	1.205	18.298
Penna.	25541.2	7456	18085.2	-	-	2.772	50.132
W. Va.	29469.7	5915	23554.7	.048	1.131	3.437	80.957
Sub-Total					4.206		230.142
Montana	1307.2	-	-	-	-	-	-
Wyoming	1600.2	-	1536.7	-	-	-	-
Colorado	13.8	-	13.8	-	-	3.426	.044
Utah	502.7	-	502.7	-	-	.290	.145
Tenn.	134.7	-	134.7	.340	.046	3.06	.412
Alabama	-	-	-	-	-	-	-
Virginia	1676.6	-	1676.6	-	-	1.786	2.994
Maryland	802.6	-	341.5	-	-	-	-
TOTAL					4.252		233.737
				1976			
Illinois	22428.8	6741	15687.8	-	-	.876	13.742
Indiana	19223.9	2	19221.9	-	-	.050	.961
Kentucky	42070.3	6729	35341.3	.046	1.626	2.900	102.49
Ohio	24029.1	6767	17262.1	-	-	1.420	24.512
Penna.	21211.9	7873	13338.9	-	-	2.730	36.415
W. Va.	29874.9	6156	23718.9	.046	.050	4.520	107.209
Sub-total					1.676		285.329
Montana	1388.4	-	-	-	-	-	-
Wyoming	2111.6	-	119	-	-	-	-
Colorado	1077.5	-	1077.5	-	-	8.882	9.566
Utah	894.2	-	894.2	-	-	-	-
Tenn.	197.8	-	197.8	-	-	.615	.550
Alabama	6.1	-	6.1	-	-	1.900	.011
Virginia	843.2	-	843.2	-	-	1.903	1.604
Maryland	1640.5	-	150	-	-	-	-
TOTAL					1.676		297.06
				1977			
Illinois	33856.1						
Indiana	19847.5						
Kentucky	41261.1						
Ohio	26593.9						
Penna.	19630.9						
W. Va	33393.8						
Sub-total							
Montana	640.8						
Wyoming	4684.5						
Colorado	932.5						
Utah	939.3						
Tenn.	153.2						
Alabama	2.2						
Virginia	1083.8						
Maryland	1065.3						
TOTAL							

* SOURCE: References (29), (30), (31)

+ SOURCE: References (20)-(25)

ORBES power plants listed in Reference 12.

TABLE 3.2.-12

HEALTH DAMAGE ATTRIBUTABLE TO COAL PROCESSING IN THE ORBES REGION IN 1975

TYPE OF HEALTH DAMAGE	No. of Cases	Health Damage Rate per 10^3 MWe generating capacity*
Accidental Death	4.252	.0605
Disabling Injury	233.737	3.3265
Non-Disabling Injury	365	5.199

* Based on the 1975 installed coal-fired electric generating capacity of 70,265 MWe.

TABLE 3.2.-13

ESTIMATED HEALTH IMPACTS FROM COAL PROCESSING, 1985 and 2000

SCENARIO	ACCIDENTAL DEATHS		DISABLING INJURIES		NON-DISABLING INJURIES	
	1985	2000	1985	2000	1985	2000
1 More Stringent Environmental Regulations	6	9	336	472	725	1019
2 Business As Usual	6	9	336	472	725	1019
2a Export of Electricity	6	10	336	541	725	1168
2b	6	10	336	540	725	1167
2c Nuclear Fuel Emphasis	6	6	336	336	725	725
2d Less Stringent Environmental Regulations	6	9	336	474	725	1024
3 Alternative Fuel Emphasis	6	7	336	408	725	882
4 Natural Gas Emphasis	6	6	336	340	725	734
5 Low Economic Growth	6	8	336	435	725	940
5a Very High Economic Growth	6	10	336	540	725	1166
6 Very Low Energy Growth	6	6	336	309	725	668
7 High Energy Growth	6	10	336	557	725	1204

Assumptions: Accident and illness rates remain constant at 1975 values, coal sources (internal and external to ORBES) remain constant and processing technology does not change.

3.3. TRANSPORTATION

A. 1975 Baseline

Coal is transported from mine to power plant by rail, water, truck, conveyor system, and/or slurry pipeline. A breakdown of the amounts shipped by the various modes in 1975 from mines and the states supplying the ORBES Region power plants with coal, as extracted from the Bureau of Mines 1975 Minerals Yearbook (1) is shown in Table 3.3.-1.

In the nation and the ORBES Region, about 65 percent of the coal mined is transported by railroad. The position of coal truck transport is also comparable to the national experience (13.3% in the ORBES states vs. 12.2% nationally). Waterway transports, however, carry a greater percentage of coal in the ORBES States, due to the availability of an extensive navigational system (rivers and the Great Lakes). At mine-mouth power plants coal is usually by conveyor belts. Accidents involving conveyor belt transportation of coal will not be discussed here because no data is available in the literature. Moreover, they are probably included with data on power plant operations or mining. Slurry pipe lines are potentially significant for future application, but in 1975 none was reported in operation in the ORBES Region.

It was not deemed feasible to determine the actual quantity of coal shipped to ORBES power plants by the three major modes of transportation. Instead, it was assumed that coal purchases by ORBES Region power plants were transported by the several modes from a mining state in the same proportion as the total coal shipped from that mining state. Thus the percentages for each mode of coal transport shown in Table 3.3.-1 was applied to the quantities of coal delivered to ORBES Region power plants in 1975

(Table 3.1.-3 in Section 3.1 - Coal Mining) to estimate the quantities shipped by railroad, water and truck. The results of these calculations are summarized in Table 3.3.-2.

It should be noted that an error is introduced by this assumption since the power plants in the region, especially those located within the same state as the supplying mines, since they are relatively close, are likely to receive a greater portion of the coal via trucks. More distant users, for economic reasons, supplied by the same mines, would use railroad transportation. Most of the truck shipments are likely to go to customers within the region and thus the quantity assigned to the power plants should be based on the relative demand from the power plants with respect to all users within the region. Considering that in 1975 the total quantity of coal shipped by truck from the mines of the ORBES Region was 65,592 million tons, this assumption could triple the size of coal transport by trucks and proportionally reduce the shape of railroads and waterways.

In the construction of Table 3.3.-2 it was also assumed that trucks are not used for inter-state transportation of coal -- a plausible assumption considering the usual short haul distance in truck transportation.

To estimate health cost for each of the three major modes of coal transportation in the base year-1975, the published health damage functions will be surveyed and applied to the data reported in Table 3.3.-2. The health damage will then be transformed into death and injury rates which are to be used in projections.

Health damage from transportation can be classified as direct and indirect. Direct damage is due to accidents, causing fatal and non-fatal injuries, each of which can be identified separately for the general public and transportation workers. Indirect damage is caused by the contribution of exhaust from locomotives, tow boats, and trucks to air pollution and possible disruption of traffic flow (especially of emergency medical service) by coal carrying units. Only direct damage can be quantified at this time, indirect damage will not be assessed in this report.

a. Railroad Transportation

Coal constituted 29.1% of the total freight tons transported by railroads in the U.S. in 1975. This is somewhat higher than the fairly constant percentage of prior years, as shown in Table 3.3.-3 (2).

The capacity of hopper cars used to transport coal varies between 55 (older cars) and 100 net tons (newer types) -- with an average of 84.3 tons for bituminous coal loaded in 1975. The average tonnage of coal loaded per car has been steadily increasing, as shown in Table 3.3.-4 (2).

Coal carrying cars can be mixed with other freight (mixed trains) or can be shipped in trains carrying coal only (unit trains). In the latter case, the typical unit train transports about 15,000 tons of coal. More than half (59.7%) of the total coal transported by rail in 1975 was in mixed trains. Both the quantity and percentage of coal shipped in unit trains has increased in 1975, as shown in Table 3.3.-5 (1), (2). Although the health impact of unit trains may be different from that caused by mixed trains, there is no data available to allow differentiation between them.

Railroad accident statistics and resulting damage are published by the Federal Railroad Administration in Accident Bulletins published annually. Until 1975 passenger and freight transport accident information was published separately, but the type of freight involved was not reported. Thus it is not possible to obtain direct information on accidents and health damage associated specifically with coal transportation. Beginning in 1975 freight and passenger traffic accident data are no longer reported separately.

Morris (3) summed up the published yearly railroad freight accidents 1966 through 1974 and calculated the deaths and injuries per ton-mile and train-mile of total freight transported. The yearly ton-miles and train-miles of total freight transport were obtained from the 1977 Yearbook of Railroad Facts (4). This information is summarized in Table 3.3.-6.

Morris (3) also estimated the casualties which could be associated with coal transport by assigning a proportionate share of all railroad casualties based on the estimated ton-miles and train-miles of coal transport involved in the generation of one GW-yr electricity output. In the process it was necessary to make additional estimates regarding the quantity of coal producing one GWe-yr, the haul length, the use of unit trains, and the train size. The casualty rates can also be expressed on a per BTU transported by estimating the average BTU per ton of coal transported (5). Morris' results, along with the underlying assumptions, are summarized in Table 3.3.-7.

Hihmomars and Associates in another study (6) apportioned the number of casualties to the coal transported by rail based on the ratio of total weight of coal shipped to the total freight tonnage carried in the same time period. The results reported were (7):

600 total deaths per 10^{16} BTU equivalent tons shipped and

5,850 total injuries per 10^{16} BUT equivalent tons shipped.

These latter numbers, as well as the casualties calculated on ton-miles basis of coal transport, tend to be appreciably higher than those calculated

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on train-mile basis (see Table 3.3.-7). This is due to the fact that coal is more dense than the average freight transported by rail. However, the transport distance is obviously a more important factor as a contributor to accidents than the weight of freight -- and coal, on the average, is transported over relatively shorter distances than other freight. Average haul length for coal is estimated at 300 miles versus over 500 miles for the railroad industry as a whole (3). Thus, the train-mile basis seems to be a more reliable approach to estimate accidental injury and death resulting from railroad transport of coal. Morris (3) also reached this conclusion in comparing his estimates with historical data.

Furthermore, in applying the casualty rates to the ORBES Region it became apparent that the 300 mile average haul distance for coal transport by rail, which is assumed in the rate calculations on train-mile basis, is not justified. About 95% of the coal delivered to the ORBES Region power plants in 1975 originated from within the six ORBES states and 71% was supplied by mines within the same state. Although data are not available on the actual haul distance of the coal transported to ORBES Region power plants, an estimate of the distances involved can be made from railroad distance to the approximate center of the ORBES Subregions from the mining states. Based on these considerations Table 3.3.-8 was prepared showing the estimated distances of coal transport by railroad (one-way).

The ton-miles of coal transported to the ORBES power plants in 1975 can be estimated by multiplying ths tons of coal delivered from a mining state to any ORBES Subregion (Table 3.3.-2) by the corresponding average one-way haul distance (Table 3.3.-8) and summing up the products for all routes involved. The result is 2.31 x 10^{10} ton-miles.

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To estimate the total train-miles of coal transport to ORBES power plants in 1975 one can assume that coal is transported in unit trains of 15,000 net tons and calculate the number of train trips needed to transport the coal from any mining state to any ORBES Subregion, multiply this estimate by the corresponding two-way distance and sum the results for all routes involved. (Transport in mixed trains would produce more train miles to deliver the same amount of coal but only a portion of the accidents could be charged to the coal transported, which would result in the same number of injuries and deaths.) The result is 3.08×10^6 train-miles.

The total ton-miles and train-miles thus calculated can be multiplied by the average casualty rates for the 1966-74 period (Table 3.3.-6) to estimate the casualties associated with railroad transportation of coal to ORBES Region power plants in 1975. The results thus obtained are given in Table 3.3.-9.

Finally, for comparison with national rates in Table 3.3.-7 one can calculate the casualty rate per unit heat value transported by dividing each casualty value with the product of the total quantity of coal transported by railroad to ORBES power plants (107,401,000 tons) and the average unit heat value of bituminous coal and lignite consumed in the U.S. in 1975 (22,800,000 BUT per ton). The results are also given in Table 3.3.-9.

b. Waterways

Table 3.3.-10 summarizes the available pertinent information on waterway transport in the U.S. for the period 1970 - 1975.

Total freight movement did not significantly change in those years. Also, the relative quantity of coal transported remained fairly constant, constituting, on a net ton basis, about 14.8% of all freight transport.

Most of the coal is transported on barges (about 83%), the rest on self-propelled vessels. The average capacity of vessels used has steadily increased, as shown in the table.

Yearly statistics on various types of casualties in waterway transport were published beginning in 1973. These data do not differentiate public or occupational casualties, nor the type of freight transported. The number of fatalities and injuries which were most likely associated with freight transport has been extracted from the statistical categories of published information and are shown in Table 3.3.-10.

Using the available casualty data, the average casualty rates per ton and per ton-miles of all freight transported can be calculated for the years of available data. The results of these calculations are given in Table 3.3.-11.

One could now attempt to follow the approach developed for railroad transportation by estimating the portion of total freight casualties which can be assigned to waterway transportation of coal, based on either the ton-miles or the vehicle-miles transported. However, the needed information is not available for coal. Furthermore, for waterway transport it seem acceptable to work purely on per ton basis. The density of materials transported in cargo barges is much more uniform compared to railroad cars and cargo barges are usually loaded to the full tonnage capacity of the vessel whatever the material transported.

The casualties which resulted from waterway transport of coal to supply ORBES Region power plants in 1975 were then estimated simply by multiplying the per ton casualty rate in Table 3.3.-11 with the total quantity of coal transported by waterway in Table 3.3.-2. The results are shown in Table 3.3.-12. This approach assumes that the average haul length of coal transported to ORBES Region power plants is not significantly different from the average haul length for all freight transport, which may not be the case. Calculation on ton-mile basis, using actual or realistic estimates of the haul distances involved, are likely to produce somewhat lower casualty figures.

The casualty rate can again be expressed for the average heat value of the coal transported. The results of these calculations are also given in Table 3.3.-12. These figures can be compared with those obtained by Morris who estimated 16.9×10^{-16} deaths and $1,655 \times 10^{-16}$ injuries per BTU transported in barges (5).

c. Trucks

A 1977 congressional report found highway transportation to be the fastest growing means of coal transport (9). The ORBES Region seems to be the major area of the U.S. employing truck coal transportation. The congressional report indicated that Pennsylvania and Ohio are the major shippers and receivers, followed by Kentucky, West Virginia, Indiana, Illinois, and New Mexico. This is quantitatively illustrated in Table 3.3.-1, which shows that 78.2% of the coal moved by truck from mines to final destinations in 1975 originated in the six ORBES states.

According to the same report, truck transportation of coal is characterized by relatively short haul distances of 50 to 75 miles and the movements are largely intrastate. Less than 20% of the total coal movement by truck is interstate and the distances traveled are relatively short. On this basis it was assumed in the construction of Table 3.3.-2 that all truck movement is intrastate. Even if this is not strictly true, if coal is transported by truck to a neighboring state, it is not likely to occur for an appreciably longer haul distance.

Highway vehicles carry 15 to 25 net tons of coal, with a maximum of about 30 tons due to weight limitations on public highways (9).

Statistics on casualties, again, are not reported separately for coal. When estimating the casualties which can be charged to coal transportation, and when estimating the portion which can be assigned to the ORBES Region, one again has to resort to the use of an indirect method. The uncertainties involved in the various assumptions which have to be made, subject the results to error.

Morris assumed an average of 30 tons load of coal per truck, an average of 100 vehicle miles per roundtrip, 3.4×10^6 tons of coal requirement for one GWe-Yr electrical output, 7 accidents per million vehicle miles, 0.03 deaths per accident, 0.5 injuries per accident, and calculated 2.4 deaths and 40 injuries per GWe-Yr (3). Bliss et al., reported casualty rates estimated at 0.032 fatalities and 0.69 non-fatal injuries for 10^{12} BTU energy shipped by truck (7).

As in the case of railroads, the density of truck cargo is greatly nonhomogenous. For this reason the same method of approach will be followed as in the case of rail transport; namely, casualties will be charged to coal transport based on its estimated share both in total ton-miles transported and total vehicle miles traveled. The true level of casualties can be expected to be between these two estimates.

Performance and casualty data for total truck transportation is summarized in Table 3.3.-13 for the period 1973-76. The casualty rates, calculated from the total column of Table 3.3.-13 are shown in Table 3.3.-14.

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Total casualties chargeable to coal transport to ORBES power plants can now be estimated using the casualty rates of Table 3.3.-14 and the 18,547,000 tons of coal estimated to be shipped to power plants by truck. Note, however, that this number can conceivably be higher, by a factor of three. The results of these calculations are summarized in Table 3.3.-15, along with the assumptions needed in the calculations. These assumptions were: average of 62.5 miles haul distance (one-way) and 25 net tons average capacity for coal transporting trucks.

The casualty rates per average unit heat value of coal transported are shown in Table 3.3.-15.

d. Summary

Accidental deaths and injuries associated with coal transported by railroad, waterway, and truck to ORBES Region power plants were estimated for the 1975 base year. The two methods of calculating accidental deaths and injuries produced a range of casualty estimates. A summary of the results is presented in Table 3.3.-16. In the last column of the table, the total casualty experience was normalized to the "standard" 1000 MW_e generating plant by dividing the number of casualties by the total 1975 ORBES Region coal fired electrical generating capacity of 70,265 MW.

As shown in the table, the total number of deaths which can be attributed to the transportation of coal to ORBES power plants in 1975 is between 12 and 49, the total number of injuries between 48 and 207. The actual numbers are expected to be closer to the lower end of the range, which was calculated using casualty appropriation based on mileage of coal transported. Most of the damage (about 85% of the deaths and 91% of the injuries) is associated with railroad transportation. Both occupational and public

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deaths and injuries are included in these estimates, although deaths are suffered mostly by the public sector while the injuries are fairly evenly distributed between the two sectors.

B. Health Impact Projection

The most direct means of estimating the health impact associated with coal transport is to multiply the 1975 normalized casualty rates (Table 3.3.-16) by the projected coal-fired electrical generating capacity for the various scenarios. The projected generating capacity by scenario is shown in Table 3.3.-17. The estimating approach, in essence, assumes that the factors which affect the casualty rate will not change appreciably between 1975 and 2000. The results of the calculation, that is the total number of deaths and injuries expected in 1985 and 2000 under the various scenarios, are shown in Table 3.3.-18.

Information which would allow evaluation of the pattern of variation of many of the factors involved is lacking; therefore, they must be assumed to remain constant. However, a few of the factors were analyzed and some were projected in the ORBES Phase II. The approach utilized in the analysis of transportation health damage functions considers the effects of the different patterns of coal mine and power plant siting in the several scenarios on coal transportation casualties. Also, lower casualty rates for railroad transportation can be utilized due to the observed steady decline during the years 1965-74. All other factors involved in the calculations are assumed constant and/or to remain the same as those used in the baseline calculations.

Projected mining activities in the year 2000 were provided by ORBES (11). The breakdown by mining state and scenario of the quantities of mined coal committed to ORBES power plants was extracted from the supplied computer printouts and are summarized in Table 3.3.-19.

Assuming that the total quantity of coal in a scenario in Table 3.3.-19 is distributed to the sub-regions in proportion to the generating capacity in the sub-region (Table 3.3.-17), the coal consumed by sub-region power plants was estimated for the year 2000, as shown in Table 3.3.-20.

Another assumption, made elsewhere in ORBES, is that existing power plants will continue to purchase coal from the same base year sources (12). It is therefore reasonable to assume that the modes of transportation will remain unchanged as well and the data in Tables 3.3.-2, 3.3.-3, 3.3.-10 and 3.3.-13 can be adopted for this portion of the future coal purchases and it is only necessary to determine the transportation characteristics of new power plants.

According to the ORBES Project description, power plants identified as "planned" or "scenario addition" will use local coal; i.e., coal mined within the same state (12). Thus, the quantities of coal use projected which is above the 1975 use will come from the same state and can be apportioned by mode of transportation in the same ratios as Table 3.3.-2 indicates for within-state use and can be assumed to be transported the same distances recorded in the baseline section.

Based upon these assumptions, it is possible to calculate the amount of coal consumed in excess of the 1975 quantities (Table 3.3.-2) for each sub-region, scenario and mode of transportation. The results of these calculations are summarized in Table 3.3.-21.

The quantity of coal burned in each sub-region reported in Table 3.3.-21 can be utilized in the manner outlined in the baseline section to calculate the ton-miles, train-miles, tons transported and vehicle-miles as needed, for each of the three major transportation modes. Adding these to the respective 1975 figures results in the desired totals for the year 2000. These are shown in Tables 3.3.-22, 3.3.-23, and 3.3.-24.

To estimate casualty rates for 1985 and 2000, available records of past casualties were analyzed U.S. railroad freight data is summarized in Table 3.3.-25 for the 1965-74 period. The same data is plotted in Figure 3.3.-1. Deaths and injuries, both per train-miles and ton-miles, indicate a declining tendency and the pattern was extrapolated to obtain 1985 and 2000 casualty rates to be used in subsequent calculations. No similar data were available for waterway and truck transportation; therefore, the casualty rates developed for 1975 were used.

Thus, using the casualty rates described in Figure 3.3.-1 for railroad, Table 3.3.-4 for waterway, and Table 3.3.-14 for truck transport, the casualties expected for 2000 were estimated from the performance data in Tables 3.3.-22, 3.3.-23, and 3.3.-24. These are summarized in Table 3.3.-26, 3.3.-27, 3.3.-28, and 3.3.-29. The values, in general, are somewhat lower than those produced by the less complicated approach which are shown in Table 3.3.-18.

As shown in Table 3.3.-29, under the case case (scenario 2) the accidental deaths related to coal transport for ORBES power generation in 2000 would be essentially the same as they were in 1975: between 12 and 50 such deaths. This is because the death rate associated with railroad transportation is projected to reduce while the generating capacity is increased. Accidental injuries, on the other hand, are expected to be about 43% lower in 2000 than they were in 1975 because the railroad injury rate is projected to reduce at a greater

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rate than deaths.

Comparison of the expected transportation health impact for the various scenarios shows that there is no significant difference between the base case (scenario 2) and the more stringent environmental regulation case (scenario 1). The low economic growth case (scenario 5), emphasis on alternative fuel (scenario 3), and the natural gas substitution case (scenario 3), in that order, are expected to result in slightly improved coal transportation health impacts when compared to the base case (scenario 2).

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12. ORBES: "Notebook," 1979.

FIGURE 3.3.-1

U.S. RAILROAD FREIGHT CASUALTY RATES

FIGURE 3.3.-1A: Death Rates

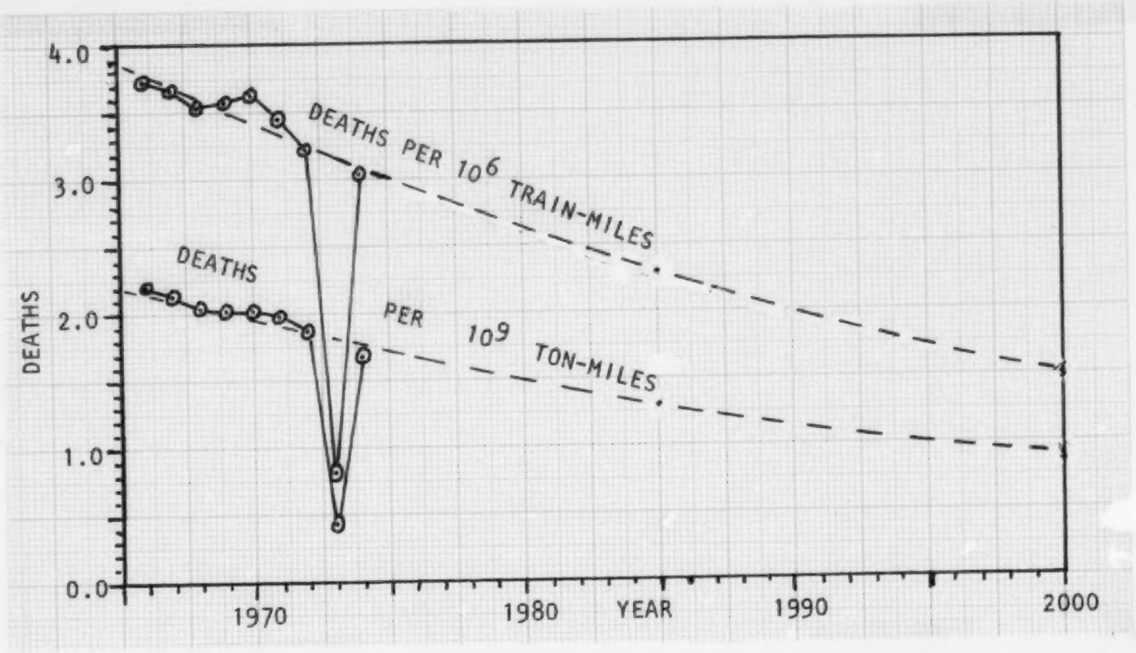

FIGURE 3.3.-1B: Injury Rates

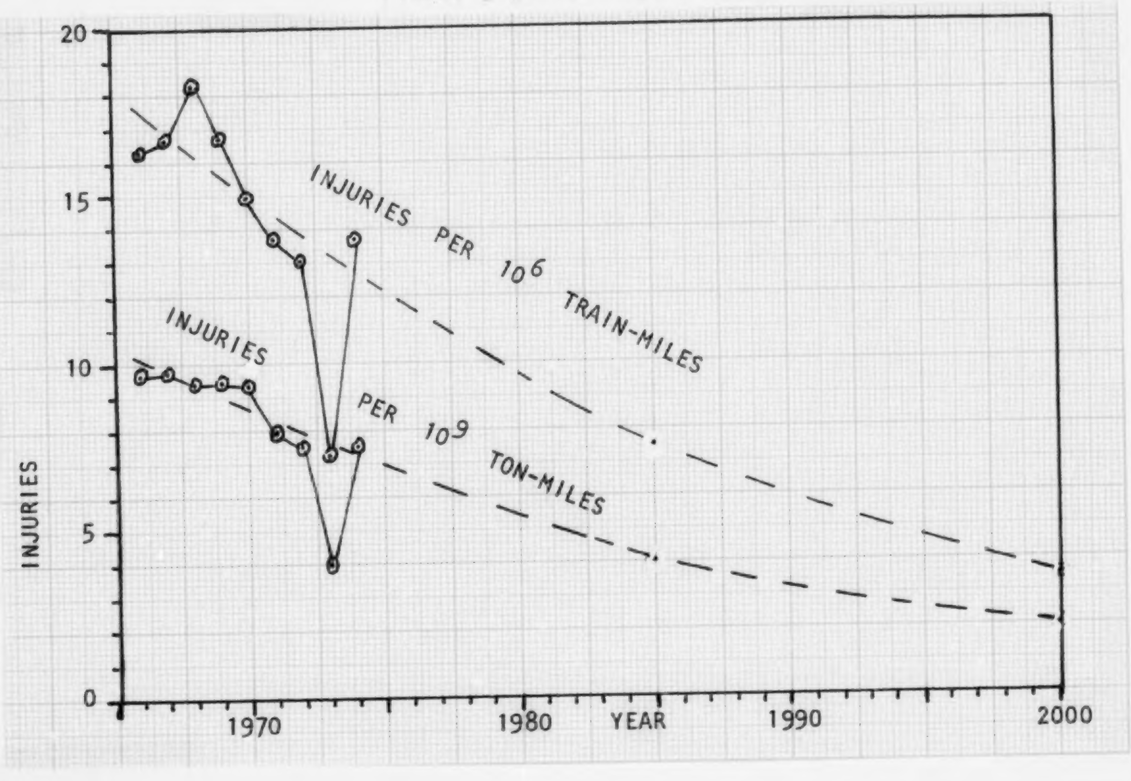

TABLE 3.3.-1

BITUMINOUS COAL AND LIGNITE LOADED FOR SHIPMENT* IN THE U.S. IN 1975, AS REPORTED BY MINE OPERATORS

(thousand short tons or %)

Mining State	Railroad		Water-way	Truck	Mine-Mouth **	Other ***	Total
	In Mixed Trains	In Unit Trains					
Illinois	24,905	21,200	2,219	4,062	7,062	89	59,537
% of total	41.8	35.6	3.7	6.8	11.9	0.2	100.0
Indiana	6,272	9,557	4,240	5,015	1	39	25,124
% of total	25.0	38.0	16.9	20.0	0.0	0.1	100.0
Kentucky	75,230	25,427	22,395	11,451	8,718	393	143,614
% of total	52.4	17.7	15.6	8.0	6.1	0.3	100.0
Ohio	6,806	14,991	6,648	12,592	5,683	49	46,769
% of total	14.6	32.1	14.2	26.9	12.1	0.1	100.0
Pennsylvania	16,205	19,950	16,219	23,702	7,456	605	84,137
% of total	19.3	23.7	19.3	28.2	8.9	0.7	100.0
West Virginia	58,047	26,039	13,871	5,225	5,915	185	109,282
% of total	53.1	23.8	2.7	4.8	5.4	0.2	100.0
Total ORBES	187,465	117,164	65,592	62,047	34,835	1,360	468,463
% of total	40.0	25.0	14.0	13.3	7.4	0.3	100.0
Colorado	2,512	4,609	--	328	706	64	8,219
% of total#	33.7	61.9	--	4.4			
Maryland	1,083	341	155	1,027	--	--	2,606
% of total#	41.6	13.1	5.9	39.4	--	--	
Montana	1,160	20,606	--	20	268	--	22,054
% of total#	5.3	94.6	--	0.1		--	
Tennessee	3,621	1,107	712	2,621	40	105	8,206
% of total#	44.9	13.7	8.8	32.5			
Utah	1,707	3,325	--	748	1,065	116	6,961
% of total#	29.5	57.5	--	12.9			
Virginia	29,326	1,056	--	5,125	--	3	35,510
% of total#	82.6	3.0	--	14.4	--		
Wyoming	3,318	13,267	--	105	7,006	110	23,806
% of total#	19.9	79.5	--	0.6			
Other States	19,420	7,061	2,635	7,344	29,623	6,530	72,613
Entire U.S.	249,612	168,536	69,094	79,365	73,543	8,288	648,438
% of total	38.5	26.0	10.7	12.2	11.3	1.3	100.0

SOURCE: Adapted from Reference (1)

*Not including amounts on which data was withheld to avoid disclosing individual company confidential data.

**Coal transported to electric utility plants adjacent to or near the mine.

***Includes coal used at mine for various purposes, and that shipped by slurry pipeline.

#Total used to calculate percentages for non-ORBES Region mining states does not include mine-mouth and other categories since these are not involved in coal transport to the ORBES Region.

TABLE 3.3.-2

ESTIMATED 1975 COAL DELIVERIES TO COMMERCIAL ELECTRIC POWER PLANTS IN THE ORBES REGION BY THE THREE MAJOR MODES OF TRANSPORTATION

(thousand short tons)

Mining State	Mode of Transport	ORBES Sub-Regions						Totals
		Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
Illinois	Rail	15,325	897	1,880				18,102
	Water	738	43	90				871
	Truck	1,350						1,350
Indiana	Rail	300	11,171	1,246	24			12,741
	Water	80	2,992	334	6			3,412
	Truck		3,539					3,539
Kentucky	Rail	957	4,123	15,181	5,055	638	2,102	28,056
	Water	213	917	3,378	1,125	142	468	6,243
	Truck			1,727				1,727
Ohio	Rail				9,354	15	299	9,668
	Water				2,853	5	91	2,949
	Truck				5,403			5,403
Pennsylvania	Rail				1,063	8,410	124	9,597
	Water				477	3,772	56	4,305
	Truck					5,513		5,513
West Virginia	Rail		60		4,584	2,412	16,327	23,383
	Water		10		756	398	2,693	3,857
	Truck						1,015	1,015
Colorado	Rail							10
	Water							-
Maryland	Rail							721
	Water							79
Montana	Rail							1,310
	Water							-
Tennessee	Rail							113
	Water							17
Utah	Rail							500
	Water							-
Virginia	Rail							1,680
	Water							-
Wyoming	Rail							1,520
	Water							-
Total Rail: 107,401 - Total Water: 21,733 - Total Truck: 18,547								

TABLE 3.3.-3

BITUMINOUS COAL ORIGINATED BY CLASS I RAILROADS IN THE U.S.

	Year				
	1971	1972	1973	1974	1975
Thousand short tons	354,954	371,135	372,220	387,704	405,047
As % of total freight tons	25.5	25.6	24.3	25.3	29.1

SOURCE: Reference (2)

TABLE 3.3.-4

AVERAGE WEIGHT OF BITUMINOUS COAL LOADED PER RAILROAD CAR IN THE U.S.

	Year				
	1971	1972	1973	1974	1975
Net short tons	77.8	80.4	81.3	83.5	84.3

SOURCE: Reference (2)

TABLE 3.3.-5

BITUMINOUS COAL AND LIGNITE SHIPPED BY UNIT TRAINS IN THE U.S.

	Year				
	1971	1972	1973	1974	1975
Thousand short tons	122,832	136,534	155,093	154,645	168,536
As % of total coal transported by railroads	34.6	36.8	41.7	39.9	41.6

SOURCE: References (1), (2)

TABLE 3.3.-6

CASUALTIES OF U.S. RAILROAD FREIGHT TRANSPORTATION

Type of Casualty	Total No. of Cases for Period	Average per 10^9 Ton-miles *	Average per 10^6 Train-miles **
Public Deaths	12,103	1.74	3.05
Public Injuries	25,460	3.66	6.42
Employee Deaths	410	0.059	0.103
Employee Injuries	30,846	4.44	7.78

*Based on 6,954 x 10^9 total ton-miles of freight transport in period.

**Based on 3,965 x 10^6 total train-miles of freight transport in period.

SOURCE: Reference (4)

TABLE 3.3.-7

ESTIMATED CASUALTY RATES ASSOCIATED WITH RAILROAD TRANSPORTATION OF COAL IN THE U.S. (a)

Type of Casualty	Casualty per GW_e-YR Generated (b)		10^{16} Casualty per BTU Transported (c)	
	Ton-mile Basis (d)	Train-mile Basis (e)	Ton-mile Basis (d)	Train-mile Basis (e)
Public Deaths	1.775	0.415	222.2	51.94
Public Injuries	3.734	0.873	467.3	109.3
Employee Deaths	0.060	0.014	7.509	1.752
Employee Injuries	4.524	1.058	566.2	132.4
Total Deaths	1.835	0.429	229.7	53.69
Total Injuries	8.258	1.931	1,033.5	241.7

(a) Based on casualties of total freight transport in Table 3.3.-6.

(b) Based on 3.4 x 10^6 tons of coal per one GW_e-YR output.

(c) Based on 2.35 x 10^7 BTU per ton of coal.

(d) Assuming 300 miles average haul length of coal.

(e) Assuming unit train transport of coal, 15,000 net tons transported by unit train, average of 600 mile round-trip distance traveled by unit train on each trip.

SOURCE: References (4), (5)

TABLE 3.3.-8

ESTIMATED AVERAGE DISTANCES OF COAL TRANSPORTED BY RAILROAD FROM MINING STATES TO ORBES SUB-REGIONS (miles)

Mining States	ORBES Sub-Regions						
	Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	Unidentified
Illinois	174	187	347				
Indiana	178	134	221	207			
Kentucky	319	192	182	250	433	292	
Ohio				134	204	185	
Pennsylvania				310	154	280	
West Virginia		370		178	177	116	
Colorado							1,180
Maryland							410
Montana							1,450
Tennessee							310
Utah							1,520
Virginia							320
Wyoming							1,380

TABLE 3.3.-9

ESTIMATED CASUALTY RESULTING FROM RAILROAD TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS IN 1975

Type of Casualty	Number of Casualty*		Casualty per 10^{16} BTU Transported#	
	Ton-Mile Basis	Train-Mile Basis	Ton-Mile Basis	Train-Mile Basis
Public Deaths	41	10	164.1	38.3
Public Injuries	85	20	345.2	80.7
Employee Deaths	2	1	5.55	1.31
Employee Injuries	103	24	418.8	97.8
Total Deaths@	42	10	169.7	39.7
Total Injuries@	188	44	764.1	178.6

*Rounded up to the next highest whole number.

#Based on 22,800,000 average BTU per ton of coal consumed in 1975 (1).

@Data may not add to totals shown because of independent rounding.

TABLE 3.3.-10

STATISTICS ON DOMESTIC WATERWAY FREIGHT TRANSPORT IN THE U.S.*

	1971	1972	1973	1974	1975	1976
Total Freight Movement						
million tons	944	985	990	979	943	976
million ton-miles	593,164	603,544	584,691	586,345	565,984	591,853
Average Capacity of Dry Cargo Barges and Scows (net tons)	1,111.5	1,124.6	1,135.0	1,166.8	1,171.4	
Bituminous Coal** (thousands of net tons)						
Barges	113,963	123,846	120,711	122,582		
Self-Propelled	26,090	25,148	23,811	22,197		
Total	140,053	148,994	144,522	144,779		
Total Coal tons as % of Total Freigh tons	14.8	15.1	14.6	14.8		
Number of Fatalities						
Freight			16	2	2	31
Cargo, Barge			0	1	1	0
Tank ships & Barges			5	3	3	4
Tugs			24	11	14	16
Total for Freight			45	17	20	51
Total for All Waterborne Transport		199	199	190	190	215
Number of Injuries						
Freight					6	8
Cargo, Barge					0	0
Tank ships & Barges					9	11
Tugs					13	24
Total for Freight					28	38
Total for All Waterborne Transport					74	123

SOURCE: References (2), (8)

* Includes coastwise, lakewise, internal, and local haul.

** As repoted by the U.S. Army Corps of Engineers. The figures include all bituminous coal transported, not only what was loaded by mine operators.

TABLE 3.3.-11

ESTIMATED CASUALTY RATES ASSOCIATED WITH U.S. WATERWAY FREIGHT TRANSPORTATION

Type of Casualty	Period	Total Number of Cases@	Casualty per 10^8 net tons hauled	Casualty per 10^{11} ton-miles transported
Deaths	1973-76	133	3.421*	5.711#
Injuries	1975-76	66	3.439**	5.700##

@ From Table 3.3.-10.
* Based on 3,888 x 10^6 tons of total freight movement.
** Based on 1,919 x 10^6 tons of total freight movement.
# Based on 2,328,873 x 10^6 ton-miles of total freight movement.
## Based on 1,157,837 x 10^6 ton-miles of total freight movement.

TABLE 3.3.-12

ESTIMATED CASUALTY RESULTING FROM WATERWAY TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS IN 1975

Type of Casualty	Number of Casualty *	Casualty per 10^{16} BTU Transported **
Deaths	1	15.00
Injuries	1	15.08

*Rounded to the next highest whole number.
**Based on 22,800,000 average BTU per ton of coal consumed in 1975 (1).

TABLE 3.3.-13

STATISTICS ON TRUCK TRANSPORTATION IN THE U.S.

	1973	1974	1975	1976	Total for 1973-76
Total Cargo Transported Intercity (million ton-miles)	505,000	495,000	454,000	510,000	1,964,000
Total Vehicle Miles Operated (millions)	267,147	267,519	274,454	306,950	1,116,070
Bituminous Coal Shipments (thousand short tons)					
By origin states	57,268	66,382			
By destination states	68,114	71,497	69,679		
Total Accidents	30,911	25,264	24,274	25,666	106,115
Total Fatalities	3,058	2,417	2,232	2,520	10,227
Injuries/Accident	0.313	0.297	0.302	0.317	0.3063

SOURCE: References (2), (8), (10)

TABLE 3.3.-14

CASUALTY RATES ASSOCIATED WITH U.S. TRUCK TRANSPORTATION 1973-76

(From the data of Table 3.3.-13)

Type of Casualty	Casualty Rate per 10^9 Ton-Miles	Casualty Rate per 10^9 Vehicle Miles
Accidents	54.03	95.08
Fatalities	5.21	9.16
Injuries*	16.55	29.12

*Based on the average injury rate of 0.3063 per all motor vehicle accidents in the 1973-76 period (10).

TABLE 3.3.-15

ESTIMATED CASUALTY RESULTING FROM TRUCK TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS IN 1975

Type of Casualty	Number of Casualty (a)		Casualty per 10^{16} BTU Transported (b)	
	Ton-Mile Basis (c)	Vehicle-Mile Basis (d)	Ton-Mile Basis (c)	Vehicle-Mile Basis (d)
Accidents	63	9	1,481	209
Fatalities	7	1	143	20.1
Injuries	20	3	454	63.9

(a) Rounded up to the next highest whole number.

(b) Based on 22,800,000 average BTU per ton of coal consumed (10).

(c) Assuming 62.5 miles average one-way haul distance.

(d) Assuming 25 net tons average truck capacity and 125 miles average round trip distance.

TABLE 3.3.-16

SUMMARY OF ESTIMATED ACCIDENTAL CASUALTY* ASSOCIATED WITH COAL TRANSPORT TO ORBES REGION POWER PLANTS IN 1975

Mode of Transportation	Type of Casualty	Number of Casualty (a)	Casualty Rate per 10^{16} BTU Transported (b)	Annual Casualty per 1000 MW_e Generating Capacity (c)
Railroad	Deaths Injuries	10 - 42 44 - 188	39.7 - 169.7 178.6 - 764.1	0.138 - 0.592 0.622 - 2.662
Waterway	Deaths Injuries	1 1	15.00 15.08	0.011 0.011
Truck	Deaths Injuries	1 - 7 3 - 20	20.1 - 143 63.9 454	0.012 - 0.086 0.038 - 0.273
Total (d)	Deaths Injuries	12 - 49 48 - 207	74.8 - 327.7 257.6 - 1233	0.161 - 0.688 0.672 - 2.946

*Indicated casualty ranges are not confidence limits but the results of different calculational approaches.

(a) Rounded up to the next highest whole number.

(b) Based on 22,800,000 average BTU per ton of coal consumed (10).

(c) Based on 70.265 GW_e-YR total ORBES Region generating capacity in 1975.

(d) Data may not add to totals shown because of independent rounding.

TABLE 3.3.-17

PROJECTED COAL-FIRED ELECTRICAL GENERATING CAPACITY IN THE ORBES REGION

(megawatts)

Scenario	Sub-Region						Total ORBES Region
	Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
				YEAR 1985			
All	14,400	18,531	18,991	19,523	15,489	13,936	100,870
				YEAR 2000			
1	20,241	26,043	26,692	27,428	21,774	19,592	141,770
1a							
1b							
1c							
1d							
2	20,241	26,043	26,692	27,428	21,774	19,592	141,770
2a							162,585
2b							162,435
2c	14,387	18,535	19,004	19,539	15,524	13,918	100,907
2d							142,435
3	17,521	22,539	23,103	23,741	18,846	16,956	122,706
4	14,581	18,756	19,224	19,753	15,678	14,112	102,104
5	18,671	24,018	24,620	25,300	20,083	18,069	130,761
5a	23,166	29,801	30,547	31,391	24,918	22,420	162,243
6	13,271	17,072	17,500	17,983	14,275	12,844	92,945
7							167,562
7a							
7b							

SOURCE: (12).

TABLE 3.3.-18

ESTIMATED YEARLY COAL TRANSPORTATION CASUALTY
BASED ON 1975 CASUALTY RATES AND
PROJECTED COAL-FIRED GENERATING CAPACITY

Scenario	Type of Casualty	
	Deaths	Injuries
YEAR 1985		
All	13 - 70	68 - 298
YEAR 2000		
1 1a 1b 1c 1d	23 - 98	96 - 418
2	23 - 98	96 - 418
2a	27 - 112	110 - 479
2b	27 - 112	110 - 479
2c	17 - 70	68 - 298
2d	23 - 98	96 - 420
3	20 - 85	83 - 362
4	17 - 71	69 - 301
5	22 - 90	88 - 386
5a	27 - 112	109 - 478
6	15 - 64	63 - 274
7 7a 7b	27 - 116	113 - 494

NOTE: Figures are rounded up to the next highest whole number.

TABLE 3.3.-19

MINED COAL COMMITTED TO ORBES POWER PLANTS IN 2000

(million short tons)

Scenario	Sub-Region						Total ORBES Region
	Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
1	33.5	39.5	85.5	39.0	38.0	52.0	287.0
1a							
1b							
1c							
1d							
2	33.5	39.0	85.5	36.0	38.0	52.0	284.0
2a	33.5	39.0	88.5	58.5	45.5	68.5	333.5
2b	33.5	39.0	85.5	39.0	38.0	52.0	287.0
2c							
2d							
3	27.5	31.5	78.0	30.0	30.5	46.0	243.5
4	20.0	22.5	69.0	21.0	23.0	40.0	195.5
5	29.0	34.5	81.0	34.5	33.5	49.0	261.5
5a							
6							
7							
7a							
7b							

SOURCE: Reference (11)

TABLE 3.3.-20

ESTIMATED COAL CONSUMPTION BY ORBES REGION ELECTRIC POWER PLANTS IN 2000

(million short tons)

Scenario	Sub-Region						Total ORBES Region
	Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
1	40.98	52.72	54.04	55.53	44.08	39.66	287.0
1a							
1b							
1c							
1d							
2	40.55	52.17	53.47	54.94	43.62	39.25	284.0
2a							333.5
2b							
2c							287.0
2d							
3	34.77	44.73	45.85	47.11	37.40	33.65	243.5
4	27.92	35.91	36.81	37.82	30.02	27.02	195.5
5	37.34	48.03	49.24	50.60	40.16	36.13	261.5
5a							
6							
7							
7a							
7b							

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TABLE 3.3.-21

ORBES POWER PLANT COAL CONSUMPTION
YEAR 2000 EXCESS OVER YEAR 1975

(million short tons per year)

Scenario	Mode of Transportation	Sub-Region						Total ORBES
		Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
1.	Railroad	19.377	18.281	22.603	13.189	10.824	13.434	97.708
	Waterway	0.933	4.896	5.030	4.023	4.855	2.216	21.953
	Truck	1.707	5.791	2.571	7.618	7.096	0.835	25.618
	Total	22.017	28.968	30.204	24.830	22.775	16.485	145.279
2.	Railroad	18.998	17.933	22.174	12.876	10.606	13.100	95.690
	Waterway	0.915	4.803	4.935	3.927	4.757	2.161	21.498
	Truck	1.674	5.681	2.523	7.437	6.952	0.814	25.081
	Total	21.587	28.418	29.634	24.240	22.315	16.075	142.269
3.	Railroad	13.912	13.238	16.474	8.717	7.650	8.536	68.527
	Waterway	0.670	3.546	3.666	2.659	3.431	1.408	15.380
	Truck	1.225	4.194	1.874	5.035	5.015	0.531	17.874
	Total	15.807	20.978	22.014	16.411	16.096	10.475	101.781
4.	Railroad	7.883	7.672	9.709	3.782	4.142	3.133	36.321
	Waterway	0.380	2.055	2.160	1.154	1.858	0.517	8.124
	Truck	0.694	2.431	1.105	2.185	2.715	0.195	9.325
	Total	8.957	12.158	12.974	7.121	8.715	3.845	53.770
5.	Railroad	16.173	15.321	19.011	10.570	8.961	10.557	80.593
	Waterway	0.779	4.103	4.230	3.224	4.019	1.741	18.096
	Truck	1.425	4.854	2.163	6.106	5.874	0.656	21.078
	Total	18.377	24.278	25.404	19.900	18.854	12.954	119.767

TABLE 3.3.-22

RAILROAD TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS

Scenario	Excess over 1975*	Total in 2000
10^{10} TON-MILES		
1.	1.4928	3.8028
2.	1.4623	3.7723
3.	1.0529	3.3629
4.	0.5675	2.8775
5.	1.2350	3.5450
10^6 TRAIN-MILES		
1.	1.9903	5.0703
2.	1.9498	5.0298
3.	1.4030	4.4839
4.	0.7566	3.8366
5.	1.6464	4.7264

* The 1975 (Base Year) performance was 2.31×10^{10} ton-miles and 3.08×10^6 train-miles.

TABLE 3.3.-23

WATERWAY TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS

(10^7 short tons)

Scenario	Excess over 1975*	Total in 2000
1.	2.1953	4.3686
2.	2.1498	4.3231
3.	1.5380	3.7113
4.	0.8124	2.9857
5.	1.8096	3.9829

* The 1975 (Base Year) performance was 2.1733×10^7 short tons.

TABLE 3.3.-24

TRUCK TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS

Scenario	Excess over 1975*	Total in 2000
10^9 TON-MILES		
1.	1.6011	2.7603
2.	1.5676	2.7268
3.	1.1171	2.2763
4.	0.5828	1.7420
5.	1.3174	2.4766
10^8 VEHICLE-MILES		
1.	1.2809	2.2083
2.	1.2541	2.1814
3.	0.8937	1.8211
4.	0.4663	1.3936
5.	1.0539	1.9813

* The 1975 (Base Year) performance was 1.1592 x 10^9 ton-miles and 0.9274 x 10^8 vehicle-miles.

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TABLE 3.3.-25

U.S. RAILROAD FREIGHT STATISTICS

Year	Total Casualty		Performance		Casualty Rates			
					Deaths		Injuries	
	Deaths	Injuries	10^9 Ton-miles	10^6 Train-miles	Per 10^9 Ton-miles	Per 10^6 Train-miles	Per 10^9 Ton-miles	Per 10^6 Train miles
1966	1632	7111	738	437	2.2114	3.7346	9.6355	16.2723
1967	1536	6997	719	420	2.1363	3.6571	9.7316	16.6595
1968	1518	6982	744	429	2.0403	3.5385	9.3844	18.2751
1969	1551	7245	768	433	2.0195	3.5820	9.4336	16.7321
1970	1554	6392	765	427	2.0314	3.6393	8.3556	14.9696
1971	1462	5868	740	430	1.9757	3.4000	7.9297	13.6465
1972	1451	5866	777	451	1.8674	3.2173	7.5495	13.0067
1973	379	3400	852	469	0.4448	0.8081	3.9906	7.2495
1974	1430	6445	851	469	1.6804	3.0490	7.5734	13.7420

SOURCE: Reference (3)

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TABLE 3.3.-26

ESTIMATED CASUALTIES RESULTING FROM RAILROAD TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS IN 2000

Scenario	Type of Casualty	Number of Casualties	
		Ton-Mile Basis	Train-Mile Basis
1.	Deaths	34.23	7.61
	Injuries	76.06	17.75
2.	Deaths	33.95	7.54
	Injuries	75.45	17.60
3.	Deaths	30.27	6.73
	Injuries	67.25	15.69
4.	Deaths	25.90	5.75
	Injuries	57.55	13.43
5.	Deaths	31.91	7.09
	Injuries	70.90	16.54

TABLE 3.3.-27

ESTIMATED CASUALTIES RESULTING FROM WATERWAY TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS IN 2000

Scenario	Deaths	Injuries
1.	1.49	1.50
2.	1.48	1.49
3.	1.27	1.28
4.	1.02	1.03
5.	1.36	1.37

TABLE 3.3.-28

ESTIMATED CASUALTIES RESULTING FROM TRUCK TRANSPORTATION OF COAL TO ORBES REGION POWER PLANTS IN 2000

Scenario	Type of Casualty	Number of Casualties	
		Ton-Mile Basis	Vehicle-Mile Basis
1.	Deaths	14.38	2.02
	Injuries	45.70	6.43
2.	Deaths	14.21	2.00
	Injuries	45.14	6.35
3.	Deaths	11.86	1.67
	Injuries	37.68	5.30
4.	Deaths	9.08	1.28
	Injuries	28.84	4.06
5.	Deaths	12.90	1.81
	Injuries	41.00	5.77

TABLE 3.3.-29

SUMMARY OF ESTIMATED ACCIDENTAL CASUALTIES ASSOCIATED WITH COAL TRANSPORT TO ORBES REGION POWER PLANTS IN 2000

	Deaths		Injuries	
Scenario	Range	Mean % Change from 1975 Base Year	Range	Mean % Change from 1975 Base Year
1. More Stringent Environmental Regulations	12 - 51	+2%	26 - 124	-43%
2. Business As Usual	12 - 50	+1%	26 - 123	-43%
3. Alternative Fuel Emphasis	10 - 44	-13%	23 - 107	-50%
4. Natural Gas Substitution	9 - 36	-26%	19 - 88	-59%
5. Low Economic Growth	11 - 47	-6%	24 - 114	-47%

NOTES: Figures rounded up to the next highest whole number. Indicated ranges are not confidence limits but the results of different calculational approaches.

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3.4. CONVERSION

Health risks, associated with the conversion of coal to energy, arise in four areas: among the population due to the release of pollutants into the atmosphere, onto land (discussed in the section on waste disposal), into water and among the workers within the power plant due to occupational injuries and disease. These four areas present varying degrees of assessment difficulty and much more quantitative evaluations have been made of air pollution than of the land pollution, water pollution and occupational health aspects.

First, there is the difference to be found between older (those built 25 years ago and before) and the more modern power plants. Secondly, there still exist some differences in operation and hence risk levels between the small and large plants, mo matter of what age. The composition of coal, water availability, and the type of pollution control measures instituted will also greatly affect the release of pollutants, and thus the resulting public health risks.

In the following section we utilize two approaches to the problem of assessing the health damage due to air quality futures based upon ORBES scenarios. It must be remembered that this assessment cannot take into account other sources of pollution or intervening conditions. The result of these analyses is an unresolved question as to the degree or extent of health damage which will ensue. One researcher (1) contends that current epidemiologic understanding points to suspended particulates as a causative agent which, at increasing concentrations in air, results in increased excess mortality from cardiovascular disease. Other researchers contend that the epidemiologic evidence implicates sulfates as well. In view of the divergence of opinion as to cause and effect we present both views.

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A. Air Quality

Health Effects on the General Public

In the introduction to this portion of the Ohio River Basin Energy Study we indicated some of the problems facing the investigator concerned with the elucidation of man-environment health relationship. In this section we attempt to quantify the possible health and disease future of the population impacted by the airborne contaminants emenating from fossil fueled power plants. This exercise is frought with many pitfalls. As stated by Hatch and Gross (2):

> The health hazards associated with community air pollution may be separated into two classes: (1) specific ill effects which are caused by exposure to particular toxic contaminants clearly identified as to nature and origin and with respect to resulting disease and (2) hazards from general community pollution which are not so specifically recognized as to cause-and-effect relationship. Within the first category are the well-recognized effects from exposure to certain particulate wastes discharged into the air by various industries. For example, an excess of pneumonia in an industrial community in Norway has been attributed to pollution of the atmosphere with manganese dioxide fume, and, in this country, cases of beryllium lung disease have been reported among residents in the neighborhood of beryllium-processing plants. Fluorosis has occurred from ingestion of fluorine compounds by grazing animals near aluminum-reduction plants, and its possible occurrence among people living in the polluted area has been a matter of concern.
>
> Concern here is with particulate exposures of the second category that are in some way unique to the problem of community air pollution. Since the health hazards associated with general community pollution are not well understood, however, it is difficult to point specifically to either direct or indirect relations between particulate components of the pollution and ill effects in man. There is no clear evidence, for example, that prolonged exposure to smoky atmospheres, such as once prevailed in Pittsburgh, produces specific illness or even nonspecific shortening of life, although the lungs of city dwellers may show mild pneumonoconiosis. Young adult males who emigrated from the urgan areas of Great Britain to New Zealand and South Africa are reported to have lung cancer rates higher than native-born men of the same ages; this has been attributed

> to early exposure to polluted air in British cities. In the United Kingdom mortality from chronic bronchitis is higher in metropolitan than in rural areas. These and other observations suggest chronic health risks in association with general community air pollution but do not specifically indict particulate matter or any other component of the polluted air.

Early interest in the effects of sulfur oxides on public health came from the well-known smog episodes in the 1950s in London, England, the Meuse valley in Belgium and in Donora, Pennsylvania. These episodes, which were associated with prolonged meteorologic temperature inversions and closely packed local concentrations of fixed sources burning soft coal with relatively high sulfur content, established clearly that when air pollution reached high levels sustained for several days, lethal effects on the population exposed could be demonstrated. The 1952 London episode, as well as subsequent ones a few years later, has been most extensively studied, and from this analysis it is evident that an increased risk of mortality from cardiopulmonary diseases occurred when both suspended particulates and sulfur oxides both exceeded 500 micrograms per cubic meter with the likelihood that transient elevations above 1000 micrograms/m^3 accounted for most of the excess mortality. The potential public health seriousness of exposure of people with varying susceptibilities to air concentrations of soft coal effluents of this amount is generally accepted, and has formed an important bench mark in the political process of air pollution control.

Such high concentrations of these pollutants have rarely ever been observed in the U.S., and now with relatively little coal used for home heating and even minimal controls on emissions from coal-burning plants, they are a thing of the past. For this reason, research in the past decade has been directed toward defining the health impacts from lower concentrations of a number of pollutants, arising from coal combustion with particular emphasis on sulfur oxides. Animal studies have generally been of limited value in defining chronic effects in special populations at risk, and thus epidemiologic research has been extensive. A number of conclusions of these studies can now be drawn, see e.g., summaries by Ferris (3) and Higgins *et al.* (4).

1. Except for the London studies, research on the specific effects of coal combustion effluents prior to 1970 cannot be relied upon to give any quantitative estimates of risk, primarily because of inadequacies in the air pollution measurements, and also because of confounding effects of cigarette smoking and exposure to indoor pollutants.

2. Recent studies, both experimental and epidemiologic, have shown that concentrations of sulfur dioxide. by itself, in the range of less than 500 micrograms/m^3 have no significant short-term effect on respiratory mechanics, symptoms or disease.

3. If acid derivatives of sulfur dioxide, such as arise from chemical reactions in stack plumes or during long-range transport of effluents, contribute to health effects observed in population studies, their contribution cannot as yet be isolated from the possible influence of other elements in the suspended particulates present in the airborne mix, such as oxides of nitrogen (largely derived from combustion sources other than power plants), and trace metals.

4. It has been possible to relate acute morbidity and mortality from cardiovascular disease, but not respiratory disease, to local concentrations of total suspended particulates in the range of 300 $\mu g/m^3$ or more (5), and the recent analysis of New York mortality data by Schimmel (6) suggests that

excess total mortality is correlated with suspended particulates, but not sulfur dioxide, in a reasonably dose-related fashion. The fact that in this study respiratory disease mortality is much less strongly correlated with airborne particulates, a phenomenon also observed in the early London studies, strongly supports the view that cardiovascular disease, which accounts for most of the remaining non-cancer deaths, is the principal cause of mortality associated with acute air pollution effects. The biological mechanisms by which inhalation of airborne particulates influences cardiovascular disease mortality remain obscure.

5. The role of airborne irritants in exacerbating asthmatic attacks has received some support from epidemiologic studies, but the particular contribution of effluents from coal-burning is far from clear, especially in view of the large number of irritants in addition to sulfur oxide derivatives that are present in urban air, and the role of indoor pollution in such studies. Some contribution of urban airborne particulates on morbidity and mortality in severely affected asthmatic patients cannot be ruled out, but there is no quantitative basis for assessing risk at this time.

6. From studies of lung cancer in occupational groups, such as coke-oven workers, roofers, and gas-plant workers, exposed to high concentrations of polynuclear aromatic hydrobarbons, it is evident that the concentrations of these combustion products in urban air (about three orders of magnitude lower than the concentrations present in the above occupations) cannot be given any significance in the excess rates of lung cancer found in urban populations. Weinberg (7) has recently concluded that all of the differences in lung cancer rates between census tracts of the Pittsburgh metropolitan area, where considerable variations in coal-derived suspended

particulates exist, can be accounted for by differences in cigarette smoking habits. One component of particulate effluents from coal combustion that has not yet been evaluated for a role in urban lung cancer rates is radioactive lead 210 and polonium 210, but at the present time the available evidence indicates that there is no association of urban air pollution, including coal-combustion effluents, with excess lung cancer risk.

7. Contributions of sulfur oxide pollution to acid rain, visibility reduction and corrosion of materials are outside the scope of this discussion.

Therefore, if at current levels of pollution the above conclusions are valid, we are left with the relationship of gross airborne particulates to cardiovascular disease mortality as a reasonably firm conclusion at this time. The contribution of sulfur emissions to this relationship is obscure. Allegations of much more significant impacts from urban air pollution, which are based on multiple regression techniques, simply display the clear inadequacy of this method for evaluating health effects in complex social groups where major confounding variables such as cigarette smoking cannot be taken into account. Radioactive heavy elements are part of the particulate phase from coal-fired plants, but estimates of risk depend on their route of exposure to human populations. For uranium, thorium and radium isotopes, ingestion from this source is negligible compared to normal soil sources of these elements in food. As mentioned above, however, by the inhalation route particularly Pb 210 and its alpha-emitting granddaughter emissions from coal-fired plants has not yet been evaluated adequately.

Dr. Radford's analysis (1) of the recent data indicates too that cardiovascular disease mortality (morbidity should reasonably closely correlate with mortality for these diseases) is increased by 5% with sustained exposure to airborne particulates at a concentration of about 350 μ g/m^3. With a proportional extrapolation to higher doses this figure is in reasonable agreement with the earlier London data. We may now estimate the public health impact of the usual concentrations of urban particulates, and the contribution of power plants, but only on the assumption that the fraction of urban particulate pollution from coal-fired power plants contributes proportionally to these effects. Until we know more about the mechanisms responsible for this relationship, it is difficult to say whether this assumption leads to over- or underestimates of the role of power plant emissions.

To apply the above risk relationship to usual population exposures to suspended particulates which are no more than an annual average of about 100 μg/m^3 for comparatively heavily polluted urban areas, some dose-response relationship must be assumed. A more difficult problem is presented if one assumes that peak concentrations are the primary factors contributing to mortality, but because the assumption of an effect from sustained exposure leads to higher risk estimates in general, it has been adopted. The linear exposure from non-combustion and industrial sources, which Dr. Radford takes here to be about 50 μg/m^3, which is found in rural areas isolated from human activities, and assumption of a value of 50 probably again will slightly overestimate the risk.

Assumption of a straight line dose-response model must be considered the upper limit case because internal exposure to cells from inhaled particulates would be expected to be under biochemical influence that would reduce the effects of low doses relative to higher doses. In particular these influences include intestinal and respiratory uptake and excretion, as well as the toxic effects of cell interactions with the offending agents, whatever they are.

Calculations of health effects per 1,000 MWe generation may be done as follows:

> The total cardiovascular mortality in the U.S. is about 600,000 per year. Exposure to particulates at levels of 100 $\mu g/m^3$ is estimated to be to no more than 1/2 the urban population, which is 2/3 of the total U.S. population. Therefore, exposure at these levels is, conservatively, to no more than 1/3 of the total U.S. population. On the basis of the straight line dose-response hypothesis, if 5% increased risk occurs at a sustained exposure to 350 $\mu g/m^3$, or 300 $\mu g/m^3$ above background, at 100 $\mu g/m^3$, or 50 $\mu g/m^3$ above background, the increased risk is $\frac{50}{300} \times 5\% = 0.83\%$. But coal-fired power plants contribute only part of the total urban particulate load. For the ORBES region Dr. Radford assumed one-fifth for this purpose. The maximum total excess cardiovascular mortality contributed per year by coal-burning power plants is therefore:
>
> $$600{,}000 \times 1/3 \times 0.0083 \times 0.2 = 333 \text{ deaths}$$
>
> The maximum contribution per 1000 MWe per year, based on

current production of 110 GWe/yr from coal plants, is thus 3.0 deaths or potentially lethal incident cases.

This estimate is clearly very uncertain, as the above assumptions attest, but Dr. Radford believes it is a defensible upper limit based on current epidemiologic evidence. The lower limit is zero, because the straight-line estimate of dose-response may well not hold at low doses, as defense mechanisms of the body may be able to cope with low-dose exposures without any significant effect on cardiovascular disease.

Although the upper limit estimate of risk to the general public is lower than others have claimed, it is by no means negligible. Indeed, if subsequent work supports a risk estimate close to the upper limit, it is evident that this problem is the principal source of health impacts to the general public from either the coal or nuclear cycles, a conclusion consistent with conventional wisdom in this field.

The above assessment is based primarily upon the particulate - cardiovascular mortality relationship. Teknekron Research, Inc., did not provide ORBES future particulate concentration data resulting in a more generalized approach to the assessment of health damage. As indicated previously, other researchers have placed greater emphasis upon the SO_2-sulfate health damage relationship. The following assessment methodology is based upon that assertion and the air quality futures supplied by Teknekron Research, Inc. However, in the last section, the health impact calculated from Dr. Radford's analysis is presented for comparison.

Available Information

SO_2 and sulfate concentrations attributable to utility emissions by 80 km grid square for the eastern U.S. were provided by Teknekron, Inc. for 1976 and for seven scenarios for 1985 and 2000. The 7 scenarios were: the base case scenario, scenario 2; the less stringent environmental regulation case, scenario 2d; the more stringent environmental regulation case, scenario 1; the natural gas emphasis case, scenario 4; and three high electrical energy growth cases, scenarios 7, 7a, and 7b. Detailed description of the model used by Teknekron to generate the concentrations for the various scenarios is published elsewhere (8).

Two kinds of population data were available: 1. T. Milke of the University of Illinois provided population projections from 1975 populations by age, sex, and race for the state portions of the ORBES Region for the year 2000. These data are summarized in Table 3.4.-1. 2. Teknekron supplied 1972 population projections for 1975, 1985, and 2000 by Air Quality Control Regions (AQCRs) for the entire eastern U.S. To obtain the ORBES Region population, AQCRs best representing the state portions of the Region were selected from the AQCR map and their populations were summed up. The AQCRs selected are listed in Table 3.4.-2 and the resulting population in Table 3.4.-3.

Since the Milke data on population by state portion were not available for 1985, for internal consistency it became necessary to rely more on the results obtained by the AQCR method of population projections. This introduced several problems.

(a) these data are not based upon the most recent U.S. Bureau of Census estimates;

(b) these data are apparently not consistent with growth assumptions made elsewhere in the ORBES study:

(c) potential changes in the age-race-sex distribution which may affect the population response to air pollution are not reflected; and

(d) as some AQCRs cut across state boundaries it was not possible to match the state portions of the ORBES region exactly.

While all of these problems are important, (b) is most important for overall consistency in the ORBES study and (d) is most important for the population exposure calculations made here. A comparison for 1975 and 2000 with the Milke data provide a check with a data set that is presumably more compatible with other growth assumptions made in the Study and with the boundaries of the air quality data. However, since the sulfate concentrations present a rather smooth surface, changing only slightly over several grid squares, the incongruity of the population and pollution data should produce no major errors in comparing the relative effects of different scenarios.

Finally, information on health damage functions relating pollutant population exposure to health effects, particularly mortality, were available from papers in the ORBES Health Effects Symposium presented by Hamilton (9) and by Ferris (10), and from additional discussion at the Symposium (11).

Approach

The approach taken was to combine pollution concentrations and population to estimate population exposure. Alternative damage functions were then applied to obtain estimates of health impacts. The principal approach taken in the calculation of population exposure was to multiply average concentration of each state portion by the exposed population and sum over the ORBES region to obtain total population exposure in the region. This was done for sulfates only, since sulfates were more likely to be associated with health damage at the concentrations found in the study than SO_2 and since the 80 km grid size was too large to adequately capture the sharp geographical variations in SO_2 levels. The calculation was carried out by state rather than grid square since population data was not available at the grid square level. On the average, the state portions of the ORBES region contain about twelve 80 km grid squares, so state-portion averages are not a large aggregation of the available air concentration data.

Grid squares best representing the state portions of the ORBES region were selected by choosing squares from the grid map provided by Teknekron, Inc., and identifying the corresponding data in the output matrix of Teknekron computer printouts. Grids were classed as entirely in the state, half in the state, or not within the state. The map showing the overlap of the selected grids and the boundaries of the actual ORBES sub-regions is presented in Figure 3.4.-1.

There are some important conceptual considerations involved in summing the products of population and pollution concentration to obtain population exposure. Such a procedure inherently assumes a linear through zero damage function since non-linear and linear-threshold functions require that population be aggregated by levels of exposure. Since the projected sulfate concentrations are only utility contributions and not estimates of total concentration, non-linear damage functions cannot be used. Even an estimate of the error introduced by the use of a linear damage function cannot be obtained without estimating total exposure levels.

Furthermore, quantitative evaluations of population exposure and health damage based on sulfate pollution alone may place undue emphasis on a single pollution index. One must be aware that a very different picture of health impact might emerge if a full range of pollutant exposures were available for evaluation. Of particular interest are total particulates, respirable particulates, hydrocarbons, nitrogen oxides, and oxidants.

Results and Discussion

Using the Milke data, the estimated regional population increase is 25% from 1975 to 2000 (Table 3.4.-1). Using the AQCR method, the increase is 14% from 1975 to 1985 and 37% from 1975 to 2000 (Table 3.4.-3). Thus, even if the pollution concentrations were to remain the same, there would still be a substantial increase in population exposure since the population is growing.

Average sulfate concentrations are given in Table 3.4.-4. As expected, these vary with each scenario. The highest concentrations were obtained for scenario 2d: 12.458 $\mu g/m^3$ overall in 1985 and 8.946 $\mu g/m^3$ overall in 2000. The lowest levels were obtained for scenario 1: 3.420 $\mu g/m^3$ overall in 1985 and 2.656 $\mu g/m^3$ overall in 2000.

The variation of sulfate concentration between state portions is almost that much pronounced but the relative position of the state portions from scenario to scenario does not change much. West Virginia shows the highest concentrations in all but one of the scenarios and Illinois is the state portion with the lowest average concentration in all of the scenarios. In all but one of the scenarios and state portions, the concentration is projected to be lower in 2000 than in 1985.

The percentage change of sulfate concentrations from the 1976 base year are given in Table 3.4.-5. Scenario 2d shows, for all state portions, an increase in 1985 but a decrease by 2000. All other scenarios show a decrease in both 1985 and 2000. The highest regional decrease is obtained in scenario 1 (76.1% in 2000), the lowest in scenario 2d (19.5% in 2000).

The calculated exposures to sulfate, as obtained by both population projections, are summarized in Table 3.4.-6. Ohio is the state portion with the highest exposure levels in all scenarios. The highest regional exposure levels were obtained for scenario 2d, the lowest for scenario 1. In all but one of the scenarios the total regional exposure is less in 2000 than in 1985, the only exception being scenario 7.

The percentage changes in population exposures from the 1975/76 base year (1975 population with 1976 sulfate concentration) are given in Table 3.4.-7. Using the AQCR approach to population projection, scenario 2d shows a regional increase for both 1985 (27.8%) and 2000 (9.4%). All other scenarios show a decrease for both years, ranging from 1.6% (scenario 7 in 2000) to 67.9% (scenario 1 in 2000). Pennsylvania shows the greatest percentage decrease (or the smallest increase) in all scenarios and both years. Kentucky and Ohio are the states with the lowest decreases (or greatest increases) in all scenarios and both years.

The Milke population data for 2000 result in reduced regional exposures from 1975/76 for all scenarios. These reductions always exceed those obtained by the AQCR approach.

Estimation of health damage resulting from increased population exposure to sulfate adds considerable uncertainly to the analysis. Health damage associated with changes in annual sulfate exposure of a few $\mu g/m^3$ annual average at exposure levels below 15 or 20 $\mu g/m^3$ annual

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average cannot be estimated with accuracy. There may be none. Based primarily on cross-sectional correlational studies, however, some quantitative damage functions have been advanced. These were renewed by Hamilton (9). The median values of the excess deaths attributable to sulfate air pollution exposure (deaths per $\mu g/m^3$ sulfate concentration) were found to range between 1 and 10 per 100,000 population. Many have criticized these studies on various grounds and some rejected the analysis producing a mortality-sulfate damage function (12). Nevertheless, the results of many other studies, especially on animals in laboratories, seem to indicate that a positive relationship between sulfates, or something closely related to them, and health damage may exist. To cover the reported range, we arbitrarily selected damage functions of 0, 3.0, and 9.0 deaths/10^5 population per $\mu g/m^3$ sulfate as expressions of the change in health status as reflected in changed mortality rate, due to sulfate exposure. Zero damage function represents no correlation between sulfate level and mortality. Nine deaths/100,000 per $\mu g/m^3$ sulfate is a very high estimate, suggested only for certain age groups of the population. Three excess deaths/100,000 per $\mu g/m^3$ seems to be a conservative median estimated for all ages of the population. However, because of the uncertainty currently associated with the nature and magnitude of the mortality-sulfate damage function, any absolute health damage calculated with the "median" value should be used with caution. The utility of the damage function, as employed in this study, lies not in the accuracy of health impacts as estimated number of deaths, but in the comparison of the impacts between the various scenarios. Since the damage function is assumed to be linear no-threshold function, the same percentage changes would be obtained for health damage using any of the proposed health damage functions.

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Aside from the present uncertainty of the damage function, its reliability as a means of calculating health damage for a given year is further complicated by the time-related changes in the scenarios. Increased air pollution will not be immediately reflected by increased mortality rate. The excess deaths which can be attributed to a certain exposure level in a given year will be distributed over the lifetime of the exposed population. Thus the health damage calculated for a given year's exposure does not occur in the same year but rather it is an estimate of the eventual impact which would be reached after continuing exposure at that level under steady-state conditions for a number of years.

The results of health damage calculations, shown in Table 3.4.-8, provide some insight into the possible range of the effect on health in the population for the scenarios examined. Although the possibility exists that attributable mortality may be as high as 25,000 deaths annually in 1975/76, the more likely range is between 0 and 8,300 deaths annually. (Zero damage function, of course, produces no deaths attributable to sulfate air pollution whatever the exposure and this was omitted from the table.) With a base mortality of about 220,000, the median damage function of 3.0 deaths/10^5 population per $\mu g/m^3$ thus assigns 3.8% or less of the total mortality to sulfate air pollution exposure for the base year. Using the AQCR population data, scenario 2d shows an increase of 0.84% in total mortality rate in 1985 and a smaller increase of 0.24% in 2000, compared with 1975/76. All other scenarios yield decreases in mortality rate between 0.04% and 1.98%. Using the Milke population data, for 2000, all scenarios show decreasing death rates of from 0.01% (scenario 2d) to 2.32% (scenario 2). The summary of this type of calculations is presented in Table 3.4.-9. To the extent that the health effects produced by air pollution are chronic, the mortality attributable to a given year's emissions may actually occur over a period of ensuing years. Of course, if the changes in sulfate level are below the threshold of effect, if it exists, there will be no impact on mortality rate.

The change in overall mortality in the ORBES Region attributable to changes in utility-produced sulfate air pollution due to differences in the seven scenarios are calculated to be between a decrease of 5900 and an increase of 2500 in the number of deaths per year using the median damage function. Effects may range from zero to almost 30,000 deaths per year under conditions assumed in certain scenario years and low and high damage functions.

It should be noted that these estimates are based on sulfates alone as an index and on a linear, no threshold damage function. While hundreds, and possibly thousands of premature deaths per year clearly are an important health concern, one must realize that this is in the context of 200,000 - 300,000 deaths per year occurring from all causes in the region. Other scenario related effects on occupational health or on the general public health through changed economic conditions or other avenues could easily overwhelm these estimates.

While these quantitative estimates of air pollution health impacts are helpful in grasping the magnitude of the impact, they must be considered in light of unquantified potential effects of air pollution and other scenario related factors.

More credence can be attached to the relative magnitudes, that is the percentage differences between the estimated impacts for the various scenarios, since these are unaffected by the assumed value of the damage function. In this respect scenario 2, the so called "Business As Usual" condition, offers an intermediate course of events: the estimated number of deaths attributable to sulfate air pollution exposure is 6,345 in 1985 and 5,127 to 5,175 in 2000. These values are neither the highest nor the lowest of the scenarios, although they are somewhat on the high side, and represent a decrease of 17% in 1985 and between 33% and 38% in 2000 with respect to 1975/76. The base mortality rate would be reduced by about 1%. These decreases in mortality reflect the decrease in power plant emissions that occurs with SIP compliance.

Non-compliance with SIP or less stringent regulations for emission control (scenario 2d) would result in a 28% increase in the number of deaths attributable to sulfate air pollution in 1985 and a 0 to 10% increase in 2000, with respect to 1975/76. The base mortality rate would be increased by less than 1% on the average.

More stringent regulations, on the other hand, (as stipulated in scenario 1) would result in a 65% reduction in attributable deaths in 1985 and a 68% to 71% reduction in 2000 with respect to 1975/76. The base mortality rate would be reduced by about 2% on the average.

Increased use of natural gas (scenario 4) would result in a 45% reduction of attributable deaths in 1985, a 57% to 61% reduction in 2000, (with respect to 1975/76) and an average reduction of about 1.5% in base mortality rate.

High electrical energy growth with the normal 35-year lifetime for generating units (scenario 7b) results in a 42% to 50% reduction in the number of air pollution caused deaths, with respect to 1975/76. Assumption of the 45-year lifetime (scenario 7) results in a very slight (2% to 15%) reduction while the assignment of new units in the order of least emission rather than least cost (scenario 7a) produces reductions comparable to scenario 7b.

The above discussed percentage reductions from the base year, as well as the percentage reductions with respect to the base case scenario (scenario 2), are shown in Table 3.4.-8.

Health Impact Calculation Based on Particulate Emissions

As discussed earlier in this section, Dr. Radford estimated that currently a maximum of 3.0 cardiovascular deaths or potentially lethal incident cases, per 1,000 MWe per year, could be attributed to the particulate matter emitted by coal-fired power plants. This damage function can also be used to estimate the current and future health impact of power generation in the ORBES region.

Thus, multiplying the damage function with the coal-fired ORBES power generation one obtains the estimated number of excess deaths that could be assigned to the burning of coal in the power plants. The result is a range of zero to 121 excess deaths in 1975 and zero to 125 excess deaths in the 1976 base year. For future years under the various scenarios the damage function can be adjusted according to the projected change in particulate emission rates and multiplied by the projected coal-fired power generation to estimate the expected health impact. Again, the cumulative 25-year deaths can be calculated by taking the average of the 1976, 1985, and 2000 yearly values. The result of these calculations is summarized in Table 3.4.-10.

As can be seem from Table 3.4-10, the magnitude of health impact estimated this way is much lower than what was obtained using the sulfate exposure which points up the current uncertainty in estimating a relevant damage function.

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However, the health impact associated with various scenarios can again be compared and the resulting picture is not much different from what was obtained using the sulfate exposure approach. The Business As Usual case (Scenario 2) would result in a reduction of the annual excess death, to about 26% of the 1976 rate, by the year 2000. Most of this reduction would be achieved before 1985.

Comparison of the cumulative excess deaths between 1975 and 2000 projected for the various scenarios to that of Scenario 2 shows that the non-compliance case (Scenario 2d) would result in a great increase (about 162%), followed by a moderate increase (46%) in the high electric growth case (Scenario 7). The strict control case (Scenario 1) results in a very small increase in the cumulative deaths because the control efforts were assumed to be mostly directed toward gasous components of power plant emissions and the particulate emissions would actually increase by 11% by 2000. Natural gas substitution (Scenario 4) will again result in a moderate reduction in the projected health damage, when compared to the Business as Usual case (Scenario 2).

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B. Water Quality

In assessing the health risks associated with the residuals of coal-fired power generation released into aquatic environment, the following two sources were utilized: (13) and (14).

There are a variety of wastewater streams associated with power plants: cooling systems, water treatment systems, boiler/generator blowdown, maintenance cleaning wastes, ash pond runoff, drainages from coal storage piles and the plant area, waste streams from air pollution (SO_2) control devices, and miscellaneous sanitary, laboratory, and construction related effluents are all sources of wastewater originating at coal-fired power plants. These are shown schematically in Figure 3.4.-2.

Table 3.4-11 categorizes the waste streams from power plants and the flow associated with these streams. They vary considerably in flow volumes, ranging from as much as 1 MGD/Mw typically for once-through cooling, to just a few gallons per day per megawatt for some cleaning operations, with recirculating cooling water blowdown and once-through ash sluicing systems being intermediate in flow at several thousand GPM/Mw.

Table 3.4.-12 lists some general properties associated with these waste streams. The composition of the intermittent smaller flows of run-off from coal piles, as well as that of the bottom and fly-ash wastewaters, is largely determined by coal composition, while many other wastes, such as cooling water, wastewater from boiler water treatment and boiler condensate blowdown are strongly influenced by added chemicals.

A large variety of organic and inorganic chemicals are utilized for water treatment, cleaning, and the control of corrosion and biofouling of cooling water systems, many of which are shown in Table 3.4.-13. These additives along with coal constituents can and do appear in these cooling water and

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wastewater effluents. Once these chemicals are emitted to surface receiving waters, primarily rivers, human exposures may occur, principally through the drinking water route.

Many pollutants found in power plant effluents can be attributed to chemicals added for control of fouling, etc., in once-through cooling water. These include biocides, fungicides, algicides, chlorinated organics, corrosion inhibitors, surfactants, wood preservatives and materials of construction.

The major chemicals added to control organisms and slime growth in once-through cooling water are chlorine and chlorinated compounds. The use of chlorine and hypochlorites can lead to the formation of chlorinated organic substances (due to chlorination of organics present in either intake water or organics added to the water by man). Some pollutants discharged in once-through cooling water may also be attributed to corrosion of materials. In a preliminary screening sampling program conducted by EPA, elements and compounds in once-through cooling water discharges were ascertained. Those found are presented in Table 3.4.-14. Further analyses were performed to determine the presence or absence of these organics on the EPA's list of 129 priority pollutants. Those compounds which were found in cooling water and also present on EPA's list of 129 priority pollutants are presented in Table 3.4.-15. In addition to the pollutants listed in Table 3.4.-15, many other compounds were identified at concentrations less than 1 ppb.

Considerable data are available regarding the concentrations of trace elements emitted in wastewater flow streams at power plants. It is clear that for four metals: chromium, copper, iron, and zinc, power plants constitute a significant, if not substantial source. In the case of chromium the 1973 estimated discharge rate was perhaps 0.5 percent of all chromium actually used

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by industry in the U.S. Similarly, it was recently estimated by the EPA that during the period 1975 to 1990 electric utilities would discharge about 50 percent of all the lead emitted to water. It is, therefore, apparent that there is a need to assess the possible impacts of the emissions of these and other trace elements as possible agents of waterborne disease.

Some typical concentrations of zinc and chromium applied as corrosion inhibitors in cooling towers are shown in Table 3.4.-16, along with information about a few other chemicals. It should be emphasized that these typical concentrations in the circulating water are in units of mg/l, and are quite substantial should they ultimately appear in a receiving stream and remain relatively undiluted. However, the volumes of such blowdown flows are much smaller than those from once-through cooling, and do in fact often receive considerable dilution by receiving waters.

The various plant processes which are associated with a cleaning or regenerative cycle, such as boiler tube, air preheater, and boiler fireside cleaning, do not produce a steady stream of pollutants, but are the sources of intermittent waste streams. Although these streams may contain amonium ions, oxidizing agents, high alkalinity, acid, high iron and copper levels, phosphates, fluoride, organics, hardness, EDTA, NTA, citrates, gluconates, chromates, nitrates, nitrites, various trace elements, and other substances, their intermittent nature probably keeps them from contributing to any chronic health effects.

Table 3.4.-17 represents typical effluent loadings generated by a coal-fired powerplant. It was assumed in the calculation of loadings in Table 3.4.-17 that cooling towers or some other means of cooling (other than once-through cooling) were used.

Possible health effects resulting from by-products (such as trace organics and elements) in coal-fired power plant discharges entering water supplies will largely depend on the type of cooling system used and the flow of receiving stream. It is likely that as the proportion of plant flow to receiving body of water flow increases, impacts will be more severe. Once-through cooling systems will have a larger discharge than recirculating cooler systems; recirculating cooling water may be more contaminated with pollutants, especially trace elements.

These trace elements are naturally present in the hydrosphere and in many cases and at most times the incremental loads from powerplants are very small. However, for some elements, such as mercury, selenium, arsenic, chromium, and lead, the added waterborne load could be substantial compared to background concentrations. In particular, situations could be encountered where there are localized impacts, such as due to low dilution, groundwater contamination, or concentration in sediments.

For example, one potential reason for concern is when, in spite of the high dilution, the possible precipitation and incorporation of heavy metals into sediments can act as a substantial source in the aquatic food chain, such as for shellfish. Thus, where an analysis indicates that the average impact of such effluents on receiving waters and ultimately drinking water is small, other waterborne routes of exposure should be considered before a hazard is judged to be unlikely. In general, however, the concentrations of trace elements in water are such that potable water sources constitute a relatively small fraction of the contributions to human body burdens compared to dietary sources. Where there is a potential increase from powerplant emissions, it is unlikely that they will constitute a danger of acute human toxicity.

The trace element occurring in plant discharges of most concern due to its loading and toxicity is chromium. Chromium may pose potential problems when background concentrations are already at high levels. Since reported chromium concentrations have varied widely in powerplant effluents, impacts due to chromium should be assessed on a plant by plant basis. Impacts due to ingested chromium, such as tubular necrosis of the kidney, occur at concentrations much higher than that expected to be present in receiving waters containing both high background concentrations of chromium and coal-fired power plant discharges having maximum flow and pollutant loadings. When attempting to evaluate the consequences of chromium in coal-fired power plant cooling water discharge, the valence states of the chromium should be ascertained. In addition, the physiological fate of chromium also requires elucidation.

Other trace elements, cadmium, selenium, arsenic and mercury, are also of some concern, along with iron and magnesium.

Iron and magnesium loadings from coal-fired powerplants may contribute to already high background concentrations, and, thereby, lead to the exceeding of water quality standards. However, there are few health effects associated with high concentrations of iron and magnesium in water. At iron and magnesium concentrations less than that which impart taste and odor problems, health problems should not result.

The organic chemicals that can appear in waste-water effluents at coal-fired steam electric powerplants appear having the greatest potential for adverse health effects. These include the biocides, fungicides and algicides added to cooling water. If chlorination is also practiced, compounds present in the intake water or those added to the water during the plant cycle may become chlorinated. If a reaction occurs between chlorine and these organics, it is likely that they will be converted to their chlorinated analogs having greater toxic and/or carcinogenic potential. Serious concern about such chlorination reactions has developed in relation to the formation of trihalomethanes in drinking water disinfection, but many other products, depending on the nature of the organic precursor, can form as well. The EPA list of 129 priority pollutant chemicals includes several of these trihalomethanes that can form in water and wastewater chlorination.

Of the organics listed in Table 3.4.-15, benzene can be categorized as a suspected human carcinogen and chloroform as an animal carcinogen. For almost all the other listed chemicals there are either very little or no available data on chronic toxicity, although acute human toxic effects are known at much higher levels of exposure. Several of these chemicals have, however, unpleasant taste and odor characteristics, and at the concentrations shown can impact unpleasant taste to fish or similarly taint drinking water. As a class halogenated organics are responsible for adverse biological reactions and are the subject of regulatory initiatives.

All of priority pollutants are now being addressed for possible control in the proposed revision of steam electric powerplant effluent limitations guidelines.

The impact of these chlorinated organics at concentrations typically encountered in coal-fired power plant discharges is largely unknown. Many of these compounds are known to kill or otherwise affect fish or zooplankton. For example, it has been reported that 5-chlorouracil and 4-chlororesorcinol can significantly lower the hatching success of carp eggs at concentrations as low as 1 μg/l. The possible impacts on water quality will be highly site-specific, and under some low flow conditions the dilutions of these cooling water effluents may be very small. Although a few of the identified organics are likely to be human carcinogens, most occur at concentrations well below known acute toxic levels, and at the same time little or no information is available regarding their chronic human effects. Whether they will result ultimately in significant water-borne human exposure depends on dilution of the wastewater streams, their ability to concentrate in the food chain, their movement and fate in natural waters, and their ability to survive drinking water treatment. However, they are of interest as an indication that a wide variety of chloro-organics can be formed in chlorinated cooling waters at powerplants.

In order to evaluate the possible ultimate human exposures to these chlororganics from powerplant effluents it is useful to first assess their potential impacts on surface water quality, particularly in comparison to the loads generated by chlorinated municipal sewage.

At this time, one can only make preliminary judgments and conclusions about the possible waterborne route impact on human health from water pollutants arising from steam electric coal-fired powerplants. There can be substantial quantities of such potentially harmful components emitted, even when compared to those associated with other anthropogenic activities. In addition to human exposure via drinking water, they could also affect human health by concentration in the aquatic food chain. However, the information available in the literature does not yet lend itself to the development of quantitative health damage functions.

C. Occupational Health Risk

W. N. Rom presented at the Symposium an up-to-date assessment of the occupational health aspects associated with the operation of fossil-fueled electric power plants. Most of the following discussion is quoted from his paper (15).

The National Occupational Hazard Survey has provided a modicum of information on power station health hazards (16). The National Occupational Hazard Survey was a two-year field study initiated by NIOSH in 1972, intended to describe the health and safety conditions in the American work environment, and to determine the extent of worker exposure to chemical and physical agents. The sample of businesses in the survey was selected by the Bureau of Labor Statistics and consisted of approximately 5,000 establishments in sixty-seven metropolitan areas throughout the U.S.

Hazard exposure data was provided for 453 occupational groups, including #433 - Electric power linemen and cablemen (43,433 workers) and #525 - Power station operators (3,340 workers). Table 3.4.-18 illustrates the number and per cent of workers exposed to the most prevalent five individual hazards from the survey (continuous noise, mineral oil, ethanol, isopropanol, and trichlorethylene). Eighty percent of power station operators were exposed to continuous noise, and 23.5% were exposed to trichlorethylene.

Using the "Occupational Mortality in Washington State 1950-1971" study by Dr. Smauel Milham (NIOSH contract) as the reference, public utility workers have increased proportional mortality ratios (PMR) of cancer of the rectum (191), asthma (184), coronary heart disease (112), and accidents caused by electrical current (449)(17). (Table 3.4.-19) Possible etiologies for such elevated PMR's other than chance or bias could be social class, sulfur-dioxide - particulate in-plant air pollution, electromagnetic radiation, solvent exposure, etc. An increased pulmonary embolism PMR in lineman may be secondary to traumatic injury.

The general work environment at a power plant is not particularly hazardous but noise levels may be excessive at many sites and several of the maintenance jobs may be especially hazardous. Noise is probably the most ubiquitous problem at coal transfer sites, conveyor belts and in the turbine room. Coal dust requires control whenever the coal is handled. Mercury in the older switches in the control headquarters may present a mercury hazard to the workers.

Flyash from the boilers may be a problem. It is considered a nuisance dust, and has a fine, sand-like quality with a variable silica content depending on the coal. Flyash exposure may occur at the base of the boiler when various doors are opened; a slight negative pressure within the boiler reduces dust exposures to flyash. A positive pressure would increase the dust exposure hazard. Loading flyash may lead to excessive dust exposures, especially for farmers removing it to place on their fields to melt snow and hasten the planting season.

Power plants have two closed cycles for water use and re-use - condensors are used to condense the steam returning from the turbines. The water in the steam cycle is distilled and kept free of impurities to reduce scale formation. Cooling water from cooling towers passes through the condensor; this water is also purified - a large water treatment plant exists which may entail exposures to chlorine gas, sulfuric acid, and sodium hydroxide. Settling ponds are used prior to any water discharge.

A wet chemistry laboratory is used to monitor water purity.

Maintenance work may prove particularly hazardous since it is an ongoing activity throughout the plant. Exposures are usually intermittent, but may be quite heavy. One of the generators was being overhauled on one tour; solvent and oil exposures may occur here. Trichlorethylene and methyl ethyl ketone exposures are not unusual. Insulation on pipes may contain asbestos; this is more common in power plants built in the pre-1970 era. Removal of the asbestos may generate a hazardous dust exposure. Scale and plaque that accumulates on steel parts may be sandblasted resulting in a silica hazard. A welding shop on the premises has exposures to various welding fumes.

The electricity generated passes through transformers prior to distribution. The transformers may contain polychlorinated biphenyls, and an exposure may potentially occur during maintenance. The electricity then passes through a sub-station where electromagnetic radiation exposures may occur.

Professor N. LeRoy Lapp has reported pathological findings on a lung biopsy of a forty-two year old boiler repairman who worked at a power generating station that burned bituminous coal (18). He was a nonsmoker who had been employed for twenty-four years. His chest X-ray was read as normal. The lung biopsy was obtained at the time of mitral valve replacement. Light microscopy revealed mild-moderate thickening of the walls of pulmonary arterioles, and focal areas of thickening and fibrosis of alveolar septae. There were also a moderate increase in the number of pigment-laden alveolar macrophages. Electron microscopy revealed thickening of the basement membrane in the alveolar walls by fibrous material and collagen fibers.

Four types of particulate matter were found in the interstitium: 1) dense needle-like material, 2) smooth, angular pieces, 3) larger rectangular chunks, and 4) granular aggregates of the previous three types of particle. Also, small, round debris (probably silica) and a few asbestos bodies within macrophages were noted. Presumably, this particulate material represented an occupational exposure to mixed dusts (flyash, asbestos, silica, coal dust) in a nonsmoking boiler repairman.

Trichlorethylene exposure may occur among maintenance employees; the main physiological response is central nervous system depression, especially from acute exposure. Other effects include visual changes, confusion, euphoria, incoordination, nausea, skin irritation and alterations in hepatic and renal function. Liver cancers in mice fed trichlorethylene by gastric intubation have been reported by the National Cancer Institute (19).

Exposures to polychlorinated biphenyls may occur to workers repairing electrical capicitors and transformers. About 95% of the 100 million capacitators produced annually in the U.S. contain PCB's, and the 135,000 PCB-containing transformers represent 5% of all transformers in the U.S. (20). The Toxic Substances Control Act of 1976 has now banned manufacture, processing, and distribution in commerce of PCB's. Health effects of PCB's were best described from the Japanese Yusho incident in 1968 where 1,200 cases were reported from persons exposed to up to 3,000 ppm of Kanechlor 400 in rice bran oil contaiminated by PCB's during a heat exchanger leak. Signs and symptoms included darkened skin, acneiform eruptions, including chloracne, eye discharges, nausea, visual changes, neurological changes, and edema and/or low birth weight among infants born from women exposed to PCB's during pregnancy. PCB's may induce hepatic microsomal enzymes, and in animals, may cause hepatic necrosis, hepatic tumors, and an altered immune response (20).

Power plant workers may be exposed to electromagnetic ratiation since there are sixty Herz electric and magnetic fields in several locations on the power plant premises. Electromagnetic radiation may cause biological effects from tissue heating, or by membrane excitation which occurs earlier. Studies of electromagnetic radiation effects have directed attention to growth and development of plants and animals, cellular and molecular aspects of cell metabolism and physiology, chromosomal changes, alterations in behavior, and the health of utility linemen (21,22). The Johns Hopkins University nine-year study of utility linemen working on energized high voltage transmission lines found no physical, mental, or emotional changes attributable to the exposure (23,24). Soviet studies of workers exposed to electromagnetic radiation in substations and switchyards found increased subjective findings, e.g., headache, fatigue, neurological and cardiovascular changes, hematological changes, and decreased sexual potency (25,26,27). Marino and Becker have found that rats exposed to a sixty Herz electric field for one month exhibited hormonal and biochemical changes similar to those caused by stress (28). In another experiment they continuously exposed three generations of rats to the same electric field and found increased infant mortality and stunted growth (28).

A preliminary study in man showed that a 1-G (45 Herz) magnetic field has a slight but statistically significant effect on cognitive skill assessed by the Wilkinson Addition Test and Response Analysis tests (29). Constant magnetic fields are reported to slow wound healing by a delay in fibrosis and fibroblast production (30).

In summary, there are multiple potential and real hazardous exposures for fossil-fuel electric power plant workers. But, there is a paucity of published information on the prevalence of occupational disease and injury rates among these workers. In 1974, Bertolett and Fox found 0.10 deaths and 3.3 non-fatal injuries per 1000 MWe plant/year (31). In 1976, Comar and Sagan estimated rates of 0.01 - 0.03 deaths and 0.9 - 1.5 injuries and disease per 1000 MWe per year (32). Lacking a national study on the health status of power plant workers these values could be accepted for impact functions for the ORBES study.

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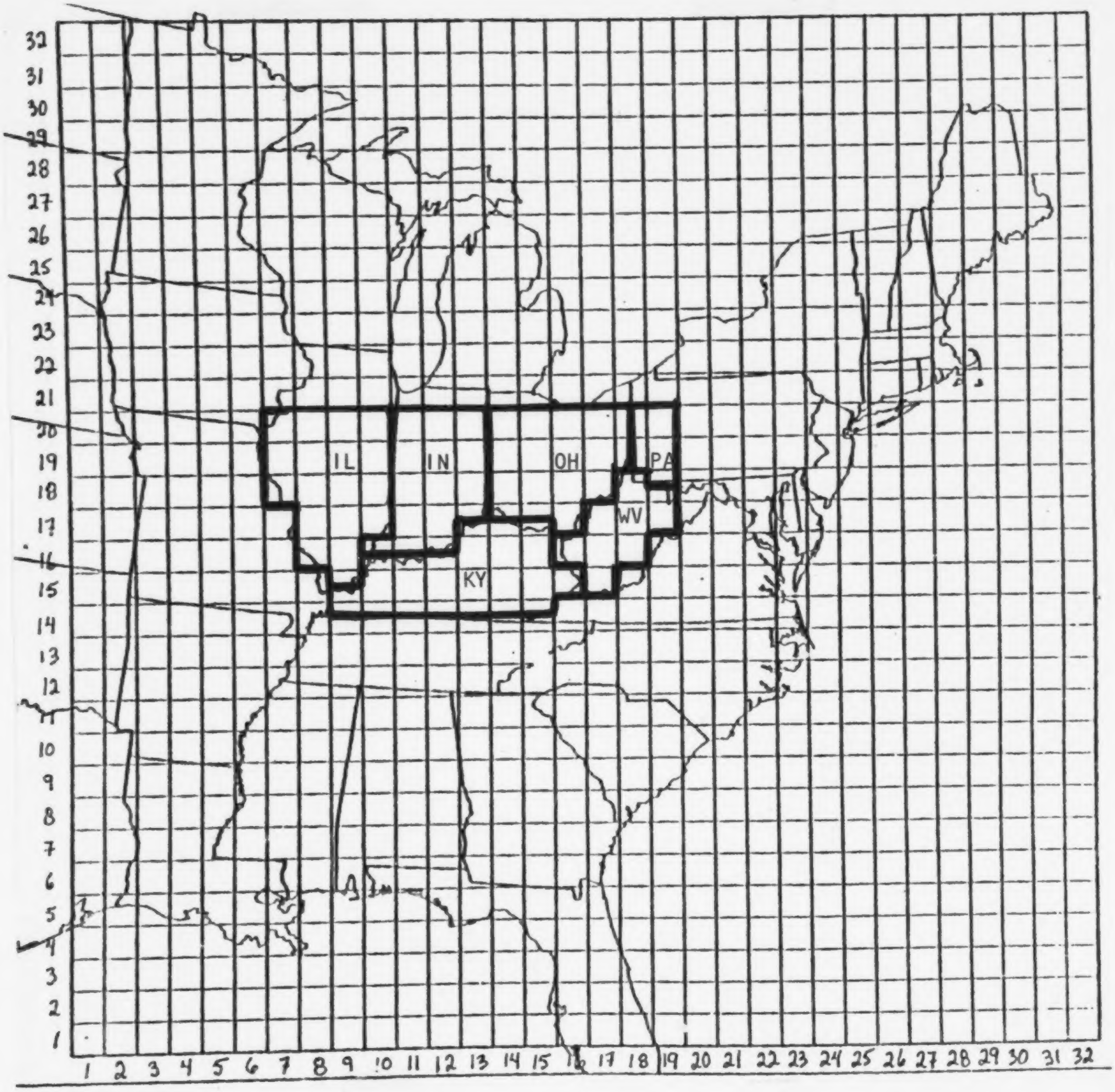
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FIGURE 3.4.-1. 80 km X 80 km GRID SQUARES SELECTED AS BEST REPRESENTING THE ORBES SUB-REGIONS (Full or half squares only)

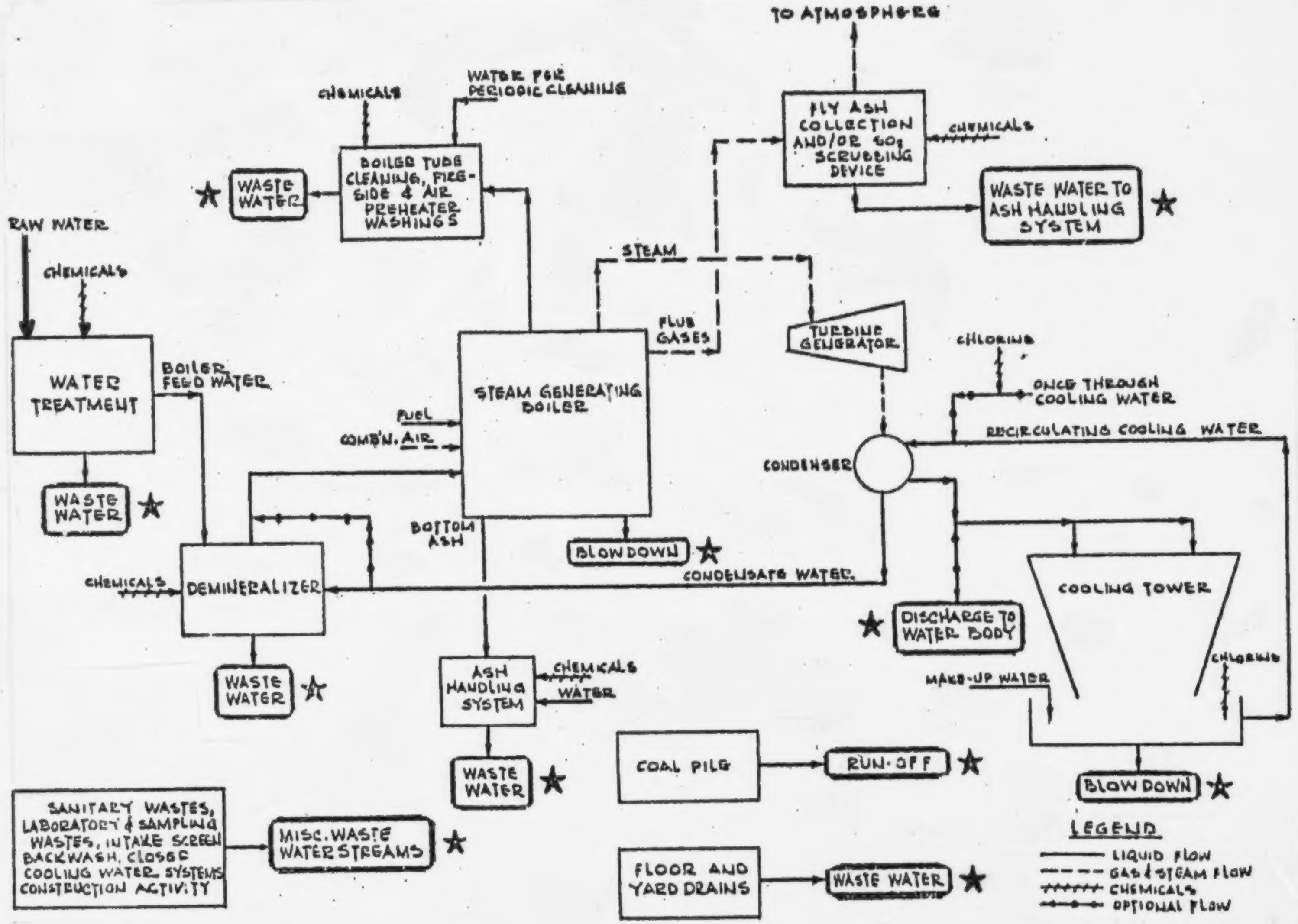
TO ATMOSPHERE
CHEMICALS
WATER FOR PERIODIC CLEANING
FLY ASH COLLECTION AND/OR SO_2 SCRUBBING DEVICE
CHEMICALS
WASTE WATER
BOILER TUBE CLEANING, FIRE-SIDE & AIR PREHEATER WASHINGS
WASTE WATER TO ASH HANDLING SYSTEM
RAW WATER
CHEMICALS
STEAM
FLUE GASES
TURBINE GENERATOR
CHLORINE
ONCE THROUGH COOLING WATER
WATER TREATMENT
BOILER FEED WATER
STEAM GENERATING BOILER
FUEL
COMB'N. AIR
RECIRCULATING COOLING WATER
CONDENSER
WASTE WATER
BOTTOM ASH
BLOWDOWN
CHEMICALS
DEMINERALIZER
CONDENSATE WATER
COOLING TOWER
DISCHARGE TO WATER BODY
WASTE WATER
ASH HANDLING SYSTEM
CHEMICALS
WATER
MAKE-UP WATER
CHLORINE
COAL PILE
RUN-OFF
WASTE WATER
BLOWDOWN
SANITARY WASTES, LABORATORY & SAMPLING WASTES, INTAKE SCREEN BACKWASH, CLOSED COOLING WATER SYSTEMS CONSTRUCTION ACTIVITY
MISC. WASTE WATER STREAMS
FLOOR AND YARD DRAINS
WASTE WATER
LEGEND
LIQUID FLOW
GAS & STEAM FLOW
CHEMICALS
OPTIONAL FLOW

FIGURE 3.4.-2. TYPICAL WATER AND WASTEWATER FLOW DIAGRAM FOR FOSSIL-FUELED STEAM ELECTRIC POWERPLANT
SOURCE: EPA 440/1-74 029-a

TABLE 3.4.-1

ESTIMATED AND PROJECTED* POPULATION OF STATE PORTIONS OF THE ORBES REGION FROM MILKE

(Population in millions)

Sub-Region	1975	2000	1975-2000 % Increase
Illinois	3.43	4.19	22.2
Indiana	4.11	5.19	26.3
Kentucky	3.39	4.25	25.4
Ohio	7.36	9.33	26.8
Pennsylvania	3.56	4.31	21.1
West Virginia	1.67	2.06	23.4
Total	23.52	29.33	24.7

*Natural increase only, excludes any migration.

SOURCE: Tom Milke, Center for Advanced Computation, University of Illinois at Urbana-Champaign.

TABLE 3.4.-2

AQCRs SELECTED AS BEST REPRESENTING STATE PORTIONS OF ORBES REGION

Sub-Region	AQCR Numbers
Illinois	65, 66, 70*, 74, 75
Indiana	76, 77, 80, 83, 84
Kentucky	72, 78, 102, 104, 105
Ohio	79, 173, 175, 176, -82, 183
Pennsylvania	197
West Virginia	101, 103, 179, 231, 232, 234, 235, 236

*Includes entire St. Louis metropolitan area.

TABLE 3.4.-3

POPULATION OF STATE PORTIONS OF THE ORBES REGION
ESTIMATED FROM POPULATION PROJECTIONS
BY AIR QUALITY CONTROL REGIONS
(Population in millions)

Sub-Region	1975	1985		2000	
	Population	Population	% Increase from 1975	Population	% Increase from 1985
Illinois	5.189	5.906	13.8	7.087	20.0
Indiana	3.788	4.431	17.0	5.488	23.9
Kentucky	2.450	2.818	15.0	3.470	23.1
Ohio	5.346	6.339	18.6	7.972	25.8
Pennsylvania	2.993	3.217	7.5	3.516	9.3
West Virginia	2.570	2.735	6.4	3.011	10.1
Total ORBES	22.336	25.446	13.9	30.544	20.0

SOURCE: The basic data were supplied by Teknekron Research, Inc. with indicated source of: 1972 OBERS Projections: Economic Activity in the U.S. by Economic Area, Water Resources Regions and Subarea, State and SMSA and Non-SMSA Portions of the Areas, Historical and Projected 1929-2020. Prepared by the U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of Economic Analysis, Regional Economic Analysis Division and by the U.S. Dept. of Agriculture, Economic Research Service, Natural Resources Economics Division for the U.S. Water Resources Council, Washington, D.C., April 1974.

TABLE 3.4.-4

SULFATE CONCENTRATION AVERAGE OF STATE PORTIONS IN THE ORBES REGION

($\mu g/m^3$)

Scenario	Year	Sub-Region						Total ORBES Region
		Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
Base Year	1976	8.589	10.954	10.762	13.050	13.729	12.741	11.111
1	1985	2.692	3.352	3.434	3.856	3.955	4.009	3.420
	2000	2.082	2.589	2.708	2.972	3.056	3.133	2.656
2	1985	6.249	7.727	7.826	9.293	9.971	9.994	8.082
	2000	4.083	5.204	5.485	6.363	6.871	7.024	5.524
2d	1985	9.529	12.154	11.853	14.627	15.471	15.100	12.458
	2000	6.954	8.704	8.650	10.307	10.886	10.812	8.946
4	1985	4.395	5.346	5.542	6.040	6.201	6.294	5.455
	2000	2.780	3.451	3.677	4.006	4.147	4.292	3.587
7	1985	6.474	7.958	8.165	9.507	10.129	10.241	8.331
	2000	5.920	7.612	7.968	9.323	10.043	10.253	8.056
7a	1985	4.015	4.954	5.193	5.676	5.866	5.964	5.091
	2000	3.276	4.043	4.189	4.525	4.594	4.688	4.093
7b	1985	4.602	5.647	5.886	6.441	6.629	6.744	5.787
	2000	3.567	4.472	4.715	5.037	5.339	5.492	4.586

TABLE 3.4.-5

CHANGE IN SULFATE CONCENTRATION

(% change from 1976 base)

Scenario	Year	Sub-Region						Total ORBES Region
		Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
1	1985	-68.7	-69.4	-68.1	-70.5	-71.2	-68.5	-69.2
	2000	-75.8	-76.4	-74.8	-77.2	-77.7	-75.4	-76.1
2	1985	-27.2	-29.5	-27.3	-28.8	-27.4	-21.6	-27.3
	2000	-52.5	-52.5	-49.0	-51.2	-50.0	-44.9	-50.3
2d	1985	+10.9	+11.0	+10.1	+12.1	+12.7	+18.5	+12.1
	2000	-19.0	-20.5	-19.6	-21.0	-20.7	-15.1	-19.5
4	1985	-48.8	-51.2	-48.5	-53.7	-54.8	-50.6	-50.9
	2000	-67.6	-68.5	-65.8	-69.3	-69.8	-66.3	-67.7
7	1985	-24.6	-27.4	-24.1	-27.1	-26.2	-19.6	-25.0
	2000	-31.1	-30.5	-26.0	-28.6	-26.8	-19.5	-27.5
7a	1985	-53.3	-54.8	-51.7	-56.5	-57.3	-53.2	-54.2
	2000	-61.9	-63.1	-61.1	-65.3	-66.5	-63.2	-63.2
7b	1985	-46.4	-48.4	-45.3	-50.6	-51.7	-47.1	-47.9
	2000	-58.5	-59.2	-56.2	-61.4	-61.1	-56.9	-58.7

TABLE 3.4.-6

POPULATION EXPOSURE TO SULFATE
(10^6 people x $\mu g/m^3$)

Scenario	Year	Sub-Region						Total ORBES Region
		Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
USING AQCR POPULATION DATA								
Base Year	1975/1976	44.6	41.5	26.4	69.8	41.1	32.7	256.1
1	1985	15.9	14.9	9.7	24.4	12.7	11.0	88.6
	2000	14.8	14.2	9.4	23.7	10.7	9.4	82.2
2	1985	36.9	34.2	22.1	58.9	32.1	27.3	211.5
	2000	28.9	28.6	19.0	50.7	24.2	21.1	172.5
2d	1985	56.3	53.9	33.4	92.7	49.8	41.3	321.4
	2000	49.3	47.8	30.0	82.2	38.3	32.6	280.2
4	1985	26.0	23.7	15.6	38.3	19.9	17.2	140.7
	2000	19.7	18.9	12.8	31.9	14.6	12.9	110.8
7	1985	38.2	35.3	23.0	60.3	32.6	28.0	217.4
	2000	42.0	41.8	27.6	74.3	35.3	30.9	251.9
7a	1985	23.7	22.0	14.6	36.0	18.9	16.3	131.8
	2000	23.2	22.2	14.5	36.1	16.2	14.1	126.3
7b	1985	27.2	25.0	16.6	40.8	21.3	18.4	149.3
	2000	25.3	24.5	16.4	40.2	18.8	16.5	141.7
USING MILKE POPULATION DATA								
Base Year	1975/1976	29.5	45.0	36.5	96.0	48.9	21.3	277.2
1	2000	8.7	13.4	11.5	27.7	13.2	6.5	81.0
2	2000	17.1	27.0	23.3	59.4	29.6	14.5	170.9
2d	2000	29.1	45.2	36.8	96.2	46.9	22.3	276.5
4	2000	11.6	17.9	15.6	37.4	17.9	8.8	109.2
7	2000	24.8	39.5	33.9	87.0	43.3	21.1	249.6
7a	2000	13.7	21.0	17.8	42.2	19.8	9.7	124.2
7b	2000	14.9	23.2	20.0	47.0	23.0	11.3	139.4

TABLE 3.4.-7

POPULATION EXPOSURE TO SULFATE

(% change from 1975/76 Base)

Scenario	Year	Sub-Region						Total ORBES Region
		Illinois	Indiana	Kentucky	Ohio	Pennsylvania	West Virginia	
USING AQCR POPULATION DATA								
1	1985	-64.3	-64.2	-63.3	-65.0	-69.0	-66.5	-65.4
	2000	-66.9	-65.8	-64.4	-66.0	-73.9	-71.2	-67.9
2	1985	-17.2	-17.5	-16.4	-15.6	-21.9	-16.5	-17.4
	2000	-35.1	-31.2	-27.8	-27.3	-41.2	-35.4	-32.6
2d	1985	+26.3	+29.8	+26.7	+32.9	+21.1	+26.1	+27.8
	2000	+10.6	+15.1	+13.8	+17.8	- 6.9	- 0.6	+ 9.4
4	1985	-41.8	-42.9	-40.8	-45.1	-51.5	-47.4	-45.1
	2000	-55.8	-54.4	-51.6	-54.2	-64.5	-60.5	-56.7
7	1985	-14.2	-15.0	-12.7	-13.6	-20.7	-14.5	-15.1
	2000	- 5.9	+ 0.7	+ 4.9	+ 6.5	-14.1	- 5.7	- 1.6
7a	1985	-46.8	-47.1	-44.5	-48.4	-54.1	-50.2	-48.7
	2000	-47.9	-46.5	-44.9	-48.3	-60.7	-56.9	-50.7
7b	1985	-39.0	-39.7	-37.1	-41.5	-48.1	-43.7	-41.7
	2000	-43.3	-40.9	-37.9	-42.4	-54.3	-49.5	-44.7
USING MILKE POPULATION DATA								
1	2000	-70.4	-70.2	-68.5	-71.1	-73.1	-69.7	-70.8
2	2000	-41.9	-40.0	-36.1	-38.2	-39.4	-32.0	-38.3
2d	2000	- 1.1	+ 0.3	+ 0.8	+ 0.1	- 4.0	+ 4.7	- 0.3
4	2000	-60.5	-60.2	-57.2	-61.1	-63.4	-58.4	-60.6
7	2000	-15.8	-12.2	- 7.2	- 9.4	-11.4	- 0.7	-10.0
7a	2000	-53.4	-53.4	-51.2	-56.0	-59.5	-54.6	-55.2
7b	2000	-49.3	-48.4	-45.1	-51.1	-52.9	-46.8	-49.7

TABLE 3.4.-8

DEATHS ATTRIBUTABLE TO SULFATE AIR POLLUTION EXPOSURE

Sce-nario	Year	ANNUAL DEATHS Assumed Damage Function (Deaths/10^5 population per $\mu g/m^3$) 3.0	 9.0	 % Change from Base Year	 % Difference with respect to Scenario 2	1975-2000 Cumulative Deaths Number *	 % Difference from Scenario 2
USING AQCR POPULATION DATA							
Base Year	1975/1976	7,683	23,049	0	-	-	-
1	1985 2000	2,658 2,466	7,974 7,398	-65.4 -67.9	-58.1 -52.3	- 106,725	- -33.3
2	1985 2000	6,345 5,175	19,035 15,525	-17.4 -32.6	0 0	- 160,025	- 0
2d	1985 2000	9,822 8,406	29,466 25,218	+27.8 + 9.4	+54.8 +62.4	- 215,925	- +34.9
4	1985 2000	4,221 3,324	12,663 9,972	-45.1 -56.7	-33.5 -35.8	- 126,900	- -20.7
7	1985 2000	6,522 7,557	19,566 22,671	-15.1 - 1.6	+ 2.8 +46.0	- 181,350	- +13.3
7a	1985 2000	3,945 3,789	11,835 11,367	-48.7 -50.7	-37.8 -26.8	- 128,475	- -19.7
7b	1985 2000	4,479 4,251	13,437 12,753	-41.7 -44.7	-29.4 -17.9	- 136,775	- -14.5
USING MILKE POPULATION DATA							
Base Year	1975/1976	8,316	24,948	0	-	-	-
1	2000	2,430	7,290	-70.8	-52.5	134,325	-20.1
2	2000	5,127	15,381	-38.3	0	168,038	0
2d	2000	8,295	24,885	- 0.3	+61.8	207,638	+23.6
4	2000	3,276	9,828	-60.6	-36.1	144,900	-13.8
7	2000	7,488	22,464	-10.0	+46.1	197,550	+17.6
7a	2000	3,726	11,178	-55.2	-27.3	150,525	-10.4
7b	2000	4,182	12,546	-49.7	-18.4	156,225	- 7.0

NOTE: Deaths are presented with more than one significant figure for purposes of further calculation only.

* Calculated with the average of the yearly deaths for 1975/76, 1985, and 2000, and the assumed damage function of 3.0.

TABLE 3.4.-9

ANNUAL DEATHS
ATTRIBUTABLE TO SULFATE AIR POLLUTION EXPOSURE

(Expressed as Change from 1975/76 Base and
as Percentage Change in Base Mortality Rate*
with Damage Function of 3 Deaths/10^5 population per $\mu g/m^3$ sulfate)

Scenario	Year	Change in Number of Annual Deaths with respect to 1975	Resulting % Change in Base Mortality Rate*
USING AQCR POPULATION DATA			
1	1985	-5025	-1.98
	2000	-5217	-1.71
2	1985	-1338	-0.53
	2000	-2508	-0.82
2d	1985	+2139	+0.84
	2000	+ 723	+0.24
4	1985	-3462	-1.36
	2000	-4359	-1.43
7	1985	-1161	-0.46
	2000	- 126	-0.04
7a	1985	-3738	-1.47
	2000	-3894	-1.28
7b	1985	-3204	-1.26
	2000	-3432	-1.13
USING MILKE POPULATION DATA			
1	2000	-5886	-2.32
2	2000	-3189	-1.26
2d	2000	- 21	-0.01
4	2000	-5040	-1.98
7	2000	- 828	-0.33
7a	2000	-4590	-1.81
7b	2000	-4134	-1.63

*Assumed to be 1%. 1975 base total deaths for all causes then = 220,000; 1985 deaths = 254,000; and 2000 deaths = 305,000. GE37 deaths attributable to air pollution in 1975 constitute 3.1% of total mortality.

TABLE 3.4.-10

CALCULATION OF DEATHS ATTRIBUTABLE TO PARTICULATE EMISSIONS
BY COAL-FIRED POWER PLANTS IN THE ORBES REGION

Scenario	Year	Particulate Emission (% Difference from Same Year of Scenario 2)	Damage Function (Deaths per 1000 MWe per year)	Projected Coal-Fired Power Generation (MWe)	Excess Cardiovascular Deaths per Year	1976-2000 Cumulative Deaths	
						Number **	% Difference from Scenario 2
Base Year	1976	N.A.	0-3.0	41,450	0-125	N.A.	N.A.
1	1985	0%	0-0.54	54,429	0- 29	-	-
	2000	+ 11%	0-0.47	76,416	0- 36	0-1584	+ 2%
2	1985	- 82%*	0-0.54	54,452	0- 29	-	-
	2000	- 86%*	0-0.42	76,541	0- 32	0-1555	0
2d	1985	+500%	0-3.24	52,888	0-171	-	-
	2000	+500%	0-2.52	76,279	0-192	0-4072	+162%
4	1985	- 12%	0-0.48	44,669	0- 21	-	-
	2000	- 16%	0-0.36	55,537	0- 20	0-1386	- 11%
7	1985			53,174		-	-
	2000	+36.8%	0-0.57	98,984	0- 57	0-2273	+ 46%

* Percent difference from Base Year.

** Obtained with the average of the 1976, 1985, and 2000 yearly deaths.

N.A. = Not applicable.

TABLE 3.4.-11

CLASSIFICATION OF WASTE STREAMS FROM COAL-FIRED POWER PLANTS

Operation	Volume (MGD)	Categorization of flow
Once-through cooling	720-2160*	High, continuous
Recirculating cooling	0.02-7.2	Intermediate, continuous
Ash pond	0.005-32	Intermediate, continuous
Air pollution control	2.86*†	Intermediate, continuous
Boiler blowdown	0.00005-1.12	Low, continuous
Coal pile drainage	0.06††	Low, intermittent
Water treatment wastes		Low, continuous
Clarification	0.083	
Ion exchange	0.001-53.3	
Evaporator	0.0001-1.06	
Others	N.D.	
Maintenance cleaning		Low, intermittent
Boiler tubes	0.00025*	
Boiler fireside	0.3 MG	
Air preheater	0.2 MG	
Misc. small equipment	N.D.	
Stack	N.D.	
Cooling tower basin	N.D.	
Miscellaneous		
Sanitary, plant laboratory, sampling systems, construction activity, etc.	N.D.	Low, intermittent

* Assuming 1000 MW plant.

† SOURCE: Chu, T. Y. J., and R. J. Ruane: Wastewater Treatment for the Coal-Fired Electric Generating Stations; Tennessee Valley Authority, Chattanooga, TN, 1978.

†† Based on 43-60 inches rainfall per year.
SOURCE: U.S.E.P.A.: Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Steam Electric Power Generating Point Source Category; EPA-440/1-74-029-a; Washington, D.C., 1974.

TABLE 3.4.-12

GENERAL PROPERTIES OF POWER PLANT WASTE STREAMS*

Parameter	Condenser cooling system		Water treatment				Chemical cleaning								
	Once-through	Recirculating	Clarification wastes	Ion exchange wastes	Evaporator	Boiler blowdown	Boiler tubes	Air pre-heater	Boiler fireside	Ash pond overflow	Coal pile drainage	Floor drains	Air pollution devices	Sanitary wastes	Lead rad wastes
Alkalinity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
BOD		✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	
COD		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	
TS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
TDS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
TSS		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Ammonia		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	
Nitrate		✓	✓	✓	✓	✓	✓			✓	✓			✓	
Phosphorous		✓	✓	✓	✓	✓	✓			✓	✓		✓	✓	
Turbidity		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Fecal coliform															✓
Acidity							✓	✓	✓	✓	✓	✓	✓		
Hardness, total		✓	✓	✓	✓	✓	✓			✓		✓	✓		
Sulfate		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Sulfite								✓	✓	✓		✓	✓		
Bromide							✓								
Chloride		✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	
Fluoride		✓	✓	✓			✓			✓					
Aluminum		✓	✓		✓	✓	✓		✓	✓	✓		✓		
Boron															✓
Chromium		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Copper	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Iron		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		
Lead										✓	✓	✓			
Magnesium		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Mercury				✓	✓		✓			✓	✓				
Nickel		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Selenium							✓			✓	✓				
Vanadium									✓	✓			✓		
Zinc		✓	✓	✓	✓	✓	✓			✓	✓				
Oil and grease				✓			✓			✓		✓	✓		
Phenols		✓	✓		✓					✓	✓				
Surfactants					✓		✓			✓		✓		✓	
Algicides	✓	✓												✓	
Chlorine	✓	✓													
Manganese		✓		✓	✓	✓	✓		✓	✓	✓		✓		

* Note: Miscellaneous streams such as laboratory sampling, stack chemical cleanings, etc. are not included since the parameters are accounted for in other streams.

SOURCE: U.S.E.P.A.: Draft Environmental Impact Statement - Ghent Generating Station Units 3 and 4; EPA-904/9-77-022, Atlanta, GA, 1977.

TABLE 3.4.-13.

CHEMICALS USED IN STEAM ELECTRIC POWER PLANTS

Use	Chemical
Coagulant in clarification water treatment	Aluminum sulfate
	Sodium aluminate
	Ferrous sulfate
	Ferric chloride
	Calcium carbonate
Regeneration of ion exchange water treatment	Sulfuric acid
	Caustic soda
	Hydrochloric acid
	Common salt
	Soda ash
	Ammonium hydroxide
Lime soda softening water treatment	Soda ash
	Lime
	Activated magnesia
	Ferric coagulate
	Dolomitic lime
Corrosion inhibition or scale prevention in boilers	Disodium phosphate
	Trisodium phosphate
	Sodium nitrate
pH control in boilers	Ammonia
	Cyclohexylamine
Sludge conditioning	Tannins
	Lignins
	Chelates such as EDTA,NTA
Oxygen scavengers in boilers	Hydrazine
	Morphaline
Boiler cleaning	Hydrochloric acid
	Citric acid
	Formic acid
	Hydroxyacetic acid
	Potassium bromate
	Phosphates
	Thiourea
	Hydrazine
	Ammonium hydroxide
	Sodium hydroxide
	Sodium carbonate
	Nitrates
Regenerants of ion exchange for condensate treatment	Caustic soda
	Sulfuric acid
	Ammonex
Corrosion inhibition or scale prevention in cooling towers	Organic phosphates
	Sodium phosphate
	Chromates
	Zinc salts
	Synthetic organics
Biocides in cooling towers	Chlorine
	Hydrochlorous acid
	Sodium hypochlorite
	Calcium hypochlorite
	Organic chromates
	Organic zinc compounds
	Chlorophenates
	Thiocyanates
	Organic sulfurs
pH control in cooling towers	Sulfuric acid
	Hydrochloric acid
Dispersing agents in cooling towers	Lignins
	Tannins
	Polyacrylonitrile
	Polyacrylamide
	Polyacrylic acids
	Polyacrylic acid salts
Biocides in condenser cooling water systems	Chlorine
	Hypochlorites
Additives to house service water systems	Chlorine
	Chromates
	Caustic soda
	Borates
	Nitrates
Additives to primary coolant in nuclear units	Boric acid
	Lithium hydroxide
	Hydrazine
Numerous uses	Numerous proprietary chemicals

SOURCE: EPA 440/1-74 029-a.

TABLE 3.4.-14

COMPONENT CONCENTRATIONS (≧1 ppb) IN ONCE THROUGH COOLING WATER FROM TWO POWER PLANTS

	Fresh water intake	Cooling discharge
Plant 1		
Composite sample:		
Benzene	3	1
1,1,1-Trichloroethane	1	2
Chloroform	10	14
Methylene chloride	7	24
Phenol	100	<1
Tetrachloroethylene	<1	3
Toluene	48	22
Cis 1,2-dichloroethylene	<1	4
Volatile organic sample:		
1,2-Dichloroethane	3	<1
1,1,1-Trichloroethane	<1	1
Chloroform	9	3
Ethylbenzene	1	2
Methylene chloride	10	8
Toluene	15	11
Plant 2		
Composite sample:		
1,1,1-Trichloroethane	1	<1
1,1-Dichloroethane	<1	1
Ethylbenzene	20	<1
Methyl chloride	22	2
Trichlorofluoromethane	40	<1
Phenol	2	14
Bis (2-ethylhexyl) phthalate	<1	11
Diethyl phthalate	<1	12
Toluene	42	2
Bis 1,2-dichloroethylene	3	<1
Volatile organic sample:		
Benzene	6	4
Chloroform	3	6
1,1-Dichloroethylene	1	4
Methylene chloride	10	19
Toluene	14	23

	Plant 1		Plant 2	
Grab sample:	Intake	Discharge	Intake	Discharge
Antimony	<5	5	<5	<5
Arsenic	13	25	<5	<5
Asbestos**	0	0	0	0
Beryllium	<5	<5	<5	<5
Cadmium	<5	<5	<5	<5
Chromium	<5	17	39	<5
Copper	<5	20	6	[illegible]
Cyanide	<20	20	<20	<20
Lead	<5	14	19	<5
Mercury	0.39	0.42	0.23	0.34
Nickel	<5	26	<5	<5
Selenium	20	18	11	<5
Silver	<5	<5	12	<5
Thallium	<5	<5	<5	<5
Zinc	<5	36	5	<5
Phenol	50	50	<10	<10

* Units are ppb for all parameters, except where noted

** Fibers/liter

SOURCE: U.S.E.P.A.: Technical Report for Revision of Steam Electric Effluent Limitations Guidelines (Draft); Washington, D.C., 1978.

TABLE 3.4.-15

PRIORITY POLLUTANTS REPORTED AS PRESENT IN POWER PLANT DISCHARGES

- Benzene
- 1,2-Dichloroethane
- 1,1,1-Trichloroethane
- 2-Chloronaphthalene
- 2,4,6-Trichlorophenol
- Chloroform
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 1,1-Dichloroethylene
- 1,2-Trans-dichloroethylene
- 2,4-Dichlorophenol
- Methylene chloride

- Chlorodibromomethane
- 2,4-Dinitrophenol
- Acenaphthylene
- Pentachlorophenol
- Phenol
- Bis (2-ethylhexyl) phthalate
- Butyl benzyl phthalate
- Di-N-butyl phthalate
- Di-n-octyl phthalate
- Diethyl phthalate
- Tetrachloroethylene
- Toluene
- Bromoform

- Antimony
- Arsenic
- Beryllium
- Cadmium
- Chromium
- Copper
- Cyanide
- Lead
- Nickel
- Silver
- Thallium
- Zinc

SOURCE: U.S.E.P.A.: Technical Report for Revision of Steam Electric Effluent Limitations Guidelines (Draft); Washington, D.C., 1978.

TABLE 3.4.-16

WASTE DISPOSAL CHARACTERISTICS (WITH CONCENTRATIONS IN mg/l) OF TYPICAL COOLING TOWER INHIBITOR SYSTEMS

Inhibitor System	Concentration in recirculating water
Chromate only	200-500 as CrO_4
Zinc Chromate	8-35 as Zn 17-65 as CrO_4
Chromate Phosphate Zinc	10-15 as CrO_4 30-45 as PO_4 8-35 as Zn
Phosphate	15-60 as PO_4
Zinc Phosphate	8-35 as Zn 15-60 as PO_4
Phosphate Organic	15-60 as PO_4 3-10 as organic
Organic only	100-200 as organic 10 est. as BOD 100 est. as COD 50 est. as CCl_4 extract 5 est. as MBAS
Organic Biocide	30 as chlorophenol 5 as sulfone 1 as thiocyanate

SOURCE: EPA 440/1-74 029-a.

TABLE 3.4.-17

ESTIMATED POLLUTANT LOADINGS FROM COAL-FIRED POWER GENERATION

Pollutant	lb/day/MW	lb/10^3 tons coal consumed	Concentration (mg/l) †
Total suspended solids	0.099*	10	2.4
Oil and grease	0.0491*	4.9	1.2
Ammonia-N	2.39×10^{-3}**	0.24	0.057
Nitrate-N	2.0×10^{-3}**	0.20	0.048
Chloride	0.22**	22.20	5.3
f.a. Chlorine	0.0062*	0.624	0.62
Sulfate	0.466*	47.10	11.2
Iron	6.5×10^{-4}*	6.6×10^{-2}	0.016
Copper	6.5×10^{-4}*	6.6×10^{-2}	0.016
Zinc	8.2×10^{-4}*	8.4×10^{-2}	0.020
Chromium	1.07×10^{-3}*	0.109	0.026
Phosphorous	8.35×10^{-3}*	0.854	0.20
Sodium	0.248**	25.9	5.94
Nickel	8.42×10^{-3}**	0.85	0.20
Magnesium	0.201**	20.3	4.81
Aluminum	2.0×10^{-3}**	0.201	0.048
Manganese	7.0×10^{-5}**	7.04×10^{-3}	0.0017
Cadmium	2.0×10^{-5}**	2.01×10^{-3}	0.00045
Selenium	7.0×10^{-5}**	7.04×10^{-3}	0.0017
Arsenic	2.0×10^{-5}**	2.0×10^{-4}	0.00048
Boron	8.3×10^{-4}**	8.4×10^{-2}	0.020
Lead	2.0×10^{-5}**	2.0×10^{-3}	0.00048
Barium	1.2×10^{-4}**	1.2×10^{-2}	0.0029
Mercury	1.6×10^{-6}**	1.6×10^{-4}	0.000038
Beryllium	3.3×10^{-6}**	3.2×10^{-4}	0.000079
Vanadium	1.67×10^{-5}**	1.6×10^{-3}	0.00040

* Assumes New Source Performance Standards.
** Assumes uncontrolled discharge.
† Assumes 1000 MW coal-fired power plant with a waste flow of 5 MGD (7.74 ft^3/sec).

SOURCE: Adapted from Argonne National Laboratory: An Integrated Assessment of Increased Coal Use in the Midwest: Impacts and Constraints, Volume II; ANL/AA-11, U.S. Department of Energy, Argonne, Illinois, 1977.

TABLE 3.4.-18

NATIONAL OCCUPATIONAL HAZARD SURVEY

	#	% of the occupational group
1) Continuous Noise		
433 Electric power linemen and cablemen	2,881	6.6%
525 Power station operators	2,673	80.0%
2) Mineral Oil		
433	26,988	62.1%
525	1,159	34.7%
3) Ethanol		
433	1,984	4.6%
525	209	6.3%
4) Isopropanol		
433	3,229	7.4%
525	488	14.6%
5) Trichlorethylene		
433	11,595	26.7%
525	789	23.6%

SOURCE: (15)

TABLE 3.4.-19

CAUSES OF DEATH OF ELECTRIC UTILITY WORKERS

Cause of Death	Proportional Mortality Ratio
Public Utility Workers	
Cancer of the rectum	191
Asthma	184
Coronary heart disease	112
Accidents caused by electrical current	449
Linemen	
Cancer of the large intestine and the rectum	157
Cancer of the respiratory system	129
Pulmonary embolism	278
Accidents due to falls	239
Accidents caused by electrical current	2,657

SOURCE: (15)

3.5 WASTE DISPOSAL

A. Generated Wastes

The major residues generated at coal fired power plants include: (a) fly ash, (b) bottom ash (defined as bottom ash and boiler slag), and (c) flue gas desulfurization (FGD) sludge resulting from the removal of sulfur dioxide from the combustion gases. Large central power stations also produce contaminated wastewaters resulting from the use of chromates for algae control in the cooling water system and operation of demineralizers and polishers to produce ultra-pure boiler feed water.

Management of the above enumerated residuals take many forms and utilities use a number of control methods. Electro-static precipitators are used to remove the fine particulates from the flue gases after the coarse fractions have been removed by centrifugal force in dust collectors. The bottom ash or boiler slag is collected at the bottom of the furnace unit after quenching with water. The bottom ashes are sluiced from the bottom collection units and transported hydraulically to an ash settling pond. Fine fly ash is collected in hydrobins, in which water has been added to the fly ash to produce a 20% moisture content mixture in order to control dust during unloading operations. The moistened fly ash is loaded into trucks and conveyed to the final disposal location.

In some installations, for example, as is done at the Bruce Mansfield Power Station in Beaver County, Pennsylvania, wet scrubbers are utilized to collect fly ash and remove sulfur dioxide in one operation. Here another waste stream is produced: flue gas desulfurization sludge. This material is usually a fifty percent solids mixture of fly ash, calcium sulfite, calcium sulfate, and unreacted lime from the wet scrubbers which use lime as the sorbent.

Flue gas desulfurization (FGD) sludge is handled in many ways depending on the economics of the specific operation. It may be conveyed hydraulically in pipe lines to the ultimate disposal location, usually a settling pond. It may be treated by any of half a dozen proprietary processes designed to chemically solidify the material for easy handling. It may be mixed with fly ash (if the fly ash is available) for the same reason. In most power plants using wet scrubbers, the sludge in the treated or untreated condition is conveyed to the ultimate disposal site by truck, rail or barge.

Disposal site operations include: (a) unloading the residual from the conveyance vehicle; (b) spreading and compacting of the fly ash, bottom ash or treated FGD sludge to obtain optimum disposal conditions. Heavy machinery such as bulldozers, compactors, vibratory compactors and spreader units are used.

Contaminated wastewater may or may not be treated at the power plant. The chromium contaminated wastewater from cooling tower operation is usually treated internally as part of the overall operation of the power plant. It is a fully automated process which does not require operating personnel except in the maintenance category. The same holds true for treating raw water to make it suitable for use in the boilers. Consequently, any reporting of accidents and injuries, if there are any, will be embedded in the power plant statistics. At this time it is not possible to enumerate or quantify the health effects of wastewater and raw water treatment operations at power plants.

B. Health Effects

Direct health impacts are related to management of sludge and fly ash at the power plant, transport of the residuals to the ultimate disposal

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location and operation of the disposal site. Accidental injuries suffered by operating personnel are the only direct and measurable health impacts.

Effects on human health can result from the dust, noise, and vibration of the machinery used in waste management in all three phases of the system. The available information regarding power plant personnel will not provide the specificity needed to develop a measure of the health impacts from internal waste management. General trucking industry statistics may be appropriate regarding noise and vibration, but the dust aspect cannot be addressed.

Fly ash, when dry, is a highly mobile material and can easily become an aerosol. It consists mainly of silicaceous fine particles in micron and submicron sizes. To ascertain the silicosis risk there is a need of developing well designed epidemiological studies of populations which are in daily, intimate contact with the fly ash.

Disposal site operators, as a group, may be exposed to noise and vibration due to the heavy equipment used and to high dust levels reached when spreading and compacting the fly ash. General data available for construction work (specifically excavation) and quarry operations may be transferrable to disposal operations. Exposure to highly variable heat and cold conditions may also have health impact on personnel.

Health effects among the general public resulting from environmental transport of toxic materials that may be contained in power plant residuals have been studied. Release of toxic trace metals from the fly ash or FGD sludge to the water environment is cited as a concern in the studies on increased use of coal. However, very little verifiable data is available at present. The U.S. Environmental Protection Agency is conducting research on impacts of fly ash and sludge disposal in order to determine the hazard

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classification of these residuals as required by the Resources Conservation and Recovery Act of 1976. Heavy metals of concern which leach from fly ash include barium vanadium, copper and zinc. However, the major impact of leaching of fly ash or FGD sludge is the increase in total dissolved solids (TDS) of the receiving waters. In the ORBES Region the dominant species in these solids is sulfates. Total dissolved solids concentrations of leachate have been reported in the 1200-4000 ppm range. If the sludge is chemically stabilized, the releases are reduced to a range of 400-800 ppm. However, the Pennsylvania Department of Environmental Resources (PennDER) has determined that electric power generation operations contribute less than five percent of the TDS releases to the Ohio River in Pennsylvania. Acid mine drainage from abandoned deep mine workings contribute 90% of the TDS burden.

C. Quantification of Health Effects

Power Plant Personnel

Accident and injury rates for residue treatment and disposal personnel should be established on the basis of tons of fly ash and sludge generated, or MWe generated. The same base units used in determining general power plant injury rates should be utilized.

At the power plant, accidents and injuries are a function of the technology used, such as sluicing of bottom ash with hydraulic transport to temporary ponds, fly ash hydrobins, sludge-materials handling; the number of workers involved, which may be zero (thus only maintenance workers may be involved). Level of operation, size of the power station, or job classification (maintenance workers, specifically mechanics) may be relevant parameters.

Noise effects will be difficult to assess for the waste management function as the maintenance workers are exposed to noise in all parts of the power plant. Noise levels developed during removal of fly ash from hydrobins may be lower than those reached in other parts of the plant and therefore be of little consequence.

Dust levels at the same activity will have some significance and could be compared to dust levels to which miners or quarry workers are exposed. The truck driver is the individual to be most likely exposed to dust during loading operations, consequently impacts from this operation should be grouped in the transportation component.

Transport Vehicle Operators

Health effects experienced during the transportation link of the waste management system will be a function of the number of operators involved, the level of operation (tons of fly ash, bottom ash, or sludge generated), the number of transport units involved (if any), and the distance between plant and disposal site (time of exposure to potential injury or chronic effects of dust). Overall trucking industry statistics may be transferrable. Unit of measurement should be ton-miles or some similar base in order to utilize existing data.

Disposal Site Operators

Health impacts are a function of: the technology used in the operations; protective measures taken, i.e., face masks, gloves, safety shoes, goggles, etc.; time of exposure to high dust levels; character of the wastes, i.e., dry or wet in reference to dust exposure; and type of heavy equipment operated.

General Population

The general population will be affected by the fugitive dust releases which travel beyond the disposal site boundaries, noise levels, and contaminated drinking water. All are highly site-specific effects, i.e., pollutant levels depend on the topography, buffering by trees or hills in the case of noise and dust, protective measures taken in site operation, i.e., noise silencers on equipment, wetting of ash to prevent fugitive dust releases, and climate. Water contamination is even more site-specific since the hydrogeology of the site and the location of the potable water supply have very significant attenuating influences on contamination.

There is no available data regarding the actual health effects of power generation residuals management on each of the above four population groups. Citizens' complaints regarding dusting conditions at the periphery of the disposal site have been addressed at public hearings, but have never actually been measured. Studies have not generally been done on the exposure of operating personnel and the general population to fly ash which is a highly silicious material. It is known that the shape and form of fly ash particles have some mitigating influence. That is to say, most of them are not in the respirable range. However, no data is presently available in order to allow an assessment.

The transport link should be similar to general trucking. Truck industry statistics may be available, but no data are available on average haul distance, tonnages of power residuals transported by truck. Some power plants use hydraulic means to transport the ash to permanent disposal ponds.

4. HEALTH ASPECTS OF NUCLEAR POWER GENERATION

The following evaluation of the health aspects of the nuclear fuel cycle was extracted from Dr. E. P. Radford's report on his support research (1) and knowledge gained from the Symposium on Energy and Human Health: Human Costs of Electric Power Generation held under ORBES auspecies in 1979 (2).

Dr. Radford (1) scaled health effects of various conversion technologies to the number of persons and activities associated with a nominal 1000 MWe power plant. The health effects have been analyzed in relation to the several definable parts of the cycle.

4.1. MINING

The two major types of uranium recovery practiced in the U.S. are strip or pit mining and underground mining. Strip is used when the ore body lies under relatively soft material at depths up to a few hundred feet; underground mining is employed when the ore body is at depths greater than 400 feet or when it lies under rock which requires a great deal of blasting to remove. Although there are considerably more underground mines operating today than strip mines, the latter generally have higher production capacities and slightly more than half of the uranium mined in the U.S. is from open pit mines. The size of open pit and underground mines vary over a wide range. The average capacity of operating open pit mines in the U.S. is about 1.5 x 10^5 MT of ore per year, and the average capacity of operating underground mines is about 2 x 10^4MT of ore annually. The ore requirements for a 1000 MWe light water reactor (LWR) are about 10^5MT (Table 4.1.-1) per year.

TABLE 4.1.-1

Radioactive Materials Handled Per Year to Supply 1000 MWe Plant

Operation	Nature of Product	Throughput/yr Metric tons (MT)	Other Waste
Mining	Uranium ore	90,000	Radioactive rubble in mine
Milling	U_3O_8	182	Tailings of ∿9000 MT/yr
Conversion	UF_6	270	
Enrichment	Enriched UF_6	52	Depleted uranium tails
Fabrication	Power plant fuel	35*	
Reactor	Spent fuel	35*	Low-level waste 230 MT
Reprocessing	High level solid waste	7	Plutonium for recycle

* Metric tons of heavy metals.

Sources of radiation exposure

1.) Direct radiation from the ore. The principal exposure is to gamma radiation from decay of the uranium or thorium series of heavy elements. The extent of exposure will depend on the richness of the ore. For open pit mining the workers receive less radiation (about half) compared to underground miners because they are more distant from the ore and are not surrounded by it. In general, with typical uranium ore conditions, underground miners accumulate about 1 rad/yr from gamma ray exposure (3). Because underground exposures to radon daughters range from one to several working levels months

(WLM)*/yr, and the working level month gives rise to a dose to the bronchial epithelium of about 6 rem on the average (4), in terms of lung cancer the contribution of the whole body gamma exposure to risk is minor. A risk of cancer at other organ sites may be contributed by the gamma radiation in underground miners, but should be insignificant for surface miners except under unusual circumstances.

2.) Airborne particulates and gases. Uranium and its daughters are released to the atmosphere when the ore body is exposed and broken up during either underground or open pit mining operations. The airborne particulate radionuclides discharged from the mines are rapidly reduced in concentration by atmospheric dispersion and approach normal background levels at the site boundaries. U.S. Bureau of Mines measurements of radon concentrations in existing open pit mines revealed no significant alpha concentrations, but for very rich ore bodies some elevation of radon daughters can occur in the working area. A report by the Atomic Energy Commission also estimated that atmospheric concentrations from open pit mining were minimal outside the work area; where scaled to 1000 MWe production requirement these emissions are less than 10% of the underground mines. For an underground uranium mine with a capacity of 1.5×10^5 MT of ore per year, the amount of radon gas emitted to the open air is estimated to be approximately 18 Ci per day (5), or about 4,500 curies/yr scaled to the production for a 1000 MWe LWR. This release rate is roughly comparable to the final tailings release, as discussed below.

The mines are generally remote from population centers, however, and there is the question of dispersion of radon (physical half-life 3.8 days, which governs the short half-life daughters) before it can affect people who may breathe the daughters (see discussion below for mill tailings). From current estimates it appears that nearly all of the exposure to radon daughters occurs locally within tens or hundreds of miles from release. In view of the low population density in mining areas, the exposure to the general population is likely to be much less than the projection cited above. Even if one assumes that an estimate of only 10% would be applicable, however, the contribution of dose to human populations from mines is still very significant, even if one ignores any contribution of the Po-210 daughter of long lived Pb-210 resulting from radon decay. Dr. Radford uses the estimate of 80 person-rem per nominal plant for lack of a better value.

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* The "working level" is a concentration of short-lived radon daughters giving rise to 1.3×10^5 MEV of alpha radiation per liter of air. The Working Level Month is a measure of cumulative exposure and is defined as exposure to one Working Level for 170 hours (hours worked/mo.).

3.) Solid and liquid waste. The solid waste from underground mining is estimated to be about equal to the volume of the processed ore. The gamma radioactivity associated with the solid waste is very small, but rubble present in mine areas can contribute to the radon present. The water pumped from both open pit and underground mines will contain dissolved and suspended uranium and its daughters. The radioactivity in the mine water is estimated at 1% of that in the ore, but it is removed from the water and returned to the ground by ion exchange during seepage through the soil. Therefore, the radioactivity reaching surface drainage is not expected to reach any significant levels. Because half the production of ore is from open-pit mining and populations are remote from the mining areas, exposures to the general population from uranium mining are considered to be of negligible health significance.

Occupational Exposure

The major source of health effects associated with the mining of uranium is the occupational exposure incurred by the underground uranium miners. These miners are exposed to radon 222 and its daughter products, which are short-lived radioactive isotopes that emit alpha radiation and are potential cancer-causing agents when inhaled.

The Mining Enforcement and Safety Administration (MESA) increased its radiation exposure monitoring during 1977. Inspectors collected 1857 radon daughter samples at 153 uranium mines (compared to 1976 figures of 1180 samples at 142 mines). Average concentrations of radon daughters have consistently decreased in uranium mines, with the average falling from 0.71 WL in 1975, to 0.58 WL in 1976, to 0.51 WL in 1977, but still well above the standard of 0.3 WL.

Table 4.1.-2 presents data collected from uranium mining companies of radiation exposures to miners in 1977. The records also show a decrease in exposure from 1.07 WLM in 1975 to 0.99 WLM in 1976 to 0.91 WLM in 1977. A discrepancy exists, however, between Federal sampling results and company records. When the Federal data of concentration of radon daughters measured in WL is converted into exposure data measured in WLM, the average exposure is 5.68 WLM in 1975, 4.64 WLM in 1976, and 4.08 WLM in 1977.

A special radiation exposures and recordkeeping audit to investigate this discrepancy was initiated in 1975, and continued until its completion in 1977. Twenty underground uranium mines employing 1604 miners were visited by MESA auditing teams. The results from the investigation are also summarized in Table 4.1.-2, which confirmed that uranium miner exposure was significantly greater than indicated by company records, with an average exposure of 4.64 WLM. According to this audit, only about 1/3 of the mines were actually in compliance with the exposure standard (3.6 WLM/yr).

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Film badge surveys in open-pit mines indicate that external whole-body radiation doses are generally less than 0.6 rem/yr. Radon-daughter concentrations are generally less than 0.3 WL, with the average concentration being 0.06 WL, or less than 10% of that found in underground mines.

TABLE 4.1.-2

1977 Uranium Mine Exposure to Radon Daughters (company records)

Total employment	Average exposure	Miners having exposure in indicated intervals, percent				
		0-1 WLM	1-2 WLM	2-3 WLM	3-4 WLM	4 WLM
5,315	.91 WLM	61.8	21.7	12.4	3.8	0.2

Radon Daughter Concentration in Underground Uranium Mines 1976-1977 (MESA Audit)

Total number of samples	Average concentration	Maximum concentration	Percentage of samples in designated range of annual exposure				
			0-4 WLM	4-8 WLM	8-12 WLM	12-24 WLM	>24 WLM
1,882	0.58 WL	24.0 WL	34.7%	25.1%	17.5%	15.5%	7.2%

In assessing current and future exposure, the number of underground uranium miners is assumed to be 6000 at the present time, and the average occupational exposure per year is assumed to be 4 WLM.

It is difficult to take account of significant changes in these exposure levels in future operations if the ore continues to be worked in small veins, with 50% or more from underground operations. A realistic appraisal suggests that with better controls demanded, 2 WLM/yr could probably be readily achieved with better mine ventilation. If a more restrictive standard than this were required, it could probably be achieved in some mines only by restricting individual exposure times, thus incureasing the number of miners and not changing the total cancers resulting. It should be noted that projections of mining activity and exposures are not greatly influenced by decisions concerning use of plutonium recycle in power production.

In calculating the maximal lifetime lung-cancer risk from occupational exposure, we assume the miner works underground 40 years, beginning at age 20.

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A lower average exposure would undoubtedly occur, but would be accompanied by a larger number of miners exposed.

The effect of whole body exposure of all workers is about 0.2 to 0.8 excess lifetime cancers per 1000 MWe/yr of nuclear power generation. For groups with significant lung dose from alpha radiation (mining, milling and fuel fabrication), additional lung cancers will occur from this exposure. These would be about 1.3 excess lung cancers from one year's exposure, about 3x as many as from whole-body exposures in the current cycle.

To this radiation excess lifetime cancers of 1.5 - 2.1 arising from annual exposures we should add a component from lung disease and accidents. Preferably these should be in terms of morbidity, but no data for morbidity exists for uranium miners. About 150 excess deaths from chronic respiratory disease and accidents have occurred in the cohort studied by Archer et al. (6) consisting of nearly 4000 underground miners exposed for about 20 years. Scaled to 200 miner-yr/1000 MWe/yr this excess mortality is about 0.4/yr. On the assumption that serious morbidity frequency is at least 8 times mortality, the added health effects are about 3, 2 from accidents and 1 from respiratory disease. This estimate is based on past practices and may be reduced in the future, but it indicates that injuries and respiratory disease contribute significantly to total morbidity in uranium mining. Morbidity from accidents in the rest of the cycle has been minimal by comparison.

In projecting the health impacts to the year 2000, Dr. Radford assumed that whole-body exposures as well as injury morbidity will be reduced by one-half and that silicosis as an occupational disease will be totally eliminated, but respiratory diseases will not be appreciably reduced. This resulted in the following projected health impacts, per 1000 MWe-yr of power production: 1.4-1.7 total incident lifetime cancer cases, 1.0 accidents and 0.5 chronic respiratory disease cases.

Application of the above rates to the 33 nuclear units of 1000 MWe capacity projected for 2000 in the nuclear scenario for the ORBES region results in 46-56 cancer cases, 33 accidental trauma and 17 chronic lung disease cases; or a total occupational health impact of 96-106 cases (of which about 1/8; i.e., 12-13 would be fatal).

4.2 PROCESSING AND REPROCESSING

A. Uranium Milling

The next stage in the uranium fuel cycle is the conversion of the mined ore containing about 0.2% U_3O_8 into a compound containing 80 to 83% U_3O_8 (yellowcake). This process takes place at uranium mills, which are located near the mines in order to minimize ore haulage distances. As of January 1, 1976, there were 17 uranium mills in operation in the U.S. The majority of the mills are conventional acid leach or alkaline leach mills, but several obtain the uranium by solution mining or from phosphoric acid treatment.

Although the uranium extraction process may vary between mills due to the chemical composition of the ores, steps common to all mills processing conventionally mined ores include crushing, grinding, chemical leaching and recovery of the uranium from the leach solutions. The problem of radiological controls is present throughout this entire process, primarily because uranium and uranium daughter products are released to the atmosphere in the form of dust and radon gas (Rn 222).

After the uranium is extracted from the ore, more than 99% of the ore material becomes the mill wastes or tailings, a slurry of sandlike material in waste solutions. The tailings are pumped to nearby sites where the solids settle out and soon accumulate to form a tailings pile.

Radiological Effluents

The radioactivity associated with uranium mill effluents are emitted from natural uranium and its daughter products (thorium 230 and radium 226) present in the ore. The milling process removes and concentrates the bulk of the natural uranium, while the majority of the radioactive daughter projects remains in the uranium-depleted solid wastes which are piped to the tailings retention system.

a.) Airborne. Radioactive airborne effluents consisting of uranium and its daughter products are released primarily from the ore crushing and grinding ventilation system, and from the yellowcake drying operations in the form of dust. Additional particulates and radon gas are also released from the tailing piles near the mill, which will be discussed in a later section. Table 4.2.-1 shows the airborne effluents which are estimated to be released from milling operations.

TABLE 4.2.-1

Uranium Milling
Airborne Releases of Radioactive Materials
(excluding tailings)

Radionuclide	Release Rate Ci/day	Site Boundary* Air Concentration pCi/m^3
Uranium	.0005	.079
Thorium 230	.00027	.043
Radium 226	.00013	.043
Radon 222	1.13	11.($\sim$0.1 WL)

*Distance to site boundary assumed to 600 meters.

It is estimated that each mill is associated with about 5000 Mwe generating capacity, therefore the mill radon output (excluding tailings) per 1000 MWe nominal plant is about 85 Ci/year, very much lower than for the mine or tailings releases.

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b.) Liquid. The liquid effluents from a mill (acid-leach) consists of waste solutions from the leaching, grinding, extraction and washing operations of the mill. This liquid is discharged with the solids into the tailing pond, which is designed to prevent contamination of ground or surface waters. About 4300 m^3 of waste solutions are generated per day, and the amounts of heavy radionuclides released in this waste water would be about 2 mCi of natural uranium, 1 mCi of Ra 226 and 50 mCi of Th 230 per day. The tailings are composed mainly of sandstone and clay particles, and constitute about 1/3 of the weight of the slurry.

c.) Released from the mill tailing piles. The mill tailing piles are the major source of radioactive materials released to the environment from mill sites. The solid waste tailings contain about 75-85% of the radioactive materials originally in the ore. While stored in the tailings retention pond, low-level activity continues to decay naturally, resulting in further discharge of radioactive effluents to the atmosphere. Radon 222 generated by the decay of Ra 226 parent and Th 230 grandparent represents the majority of the total radon annual fuel requirements for a 1000 MWe plant, not all of which will reach the atmosphere.

Studies of concentrations in air near mill tailing piles have indicated that at distances beyond 0.5 mile in the prevailing wind direction, radon concentrations are not significantly higher than background levels in these areas. The rate of radon gas escape to the atmosphere from the tailings site of a 1.5 x 10^6 kg yellowcake mill after 10 years of operation is estimated to be about 3000 Ci/yr. The rate may vary with location, however, due to the effects of weather conditions such as wind or precipitation. A pile saturated with water may have its radon release rate decreased by a factor of 25 because of decay during diffusion to the surface.

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Unlike the radon releases from uranium mines, which for all practical purposes end when the mine is shut down and sealed off, releases from mill tailings continue after the mill has been closed. This is because one source of the radon gas, thorium 230, has a very long radioactive half-life (8×10^4 years).

The tailing piles also release radioactive materials such as waterborne radionuclides leached out by precipitation, surface runoff and waste solutions. Although the movement of radioactive materials through seepage can be expected to be very slow, seepage surveillance is required to prevent unacceptable contamination of local water sources. Leaching into human water supplies can constitute a significant human exposure route.

Occupational exposures:

Film badge surveys conducted in uranium mills indicate that external whole body radiation doses to employees are generally less than 600 mrem per year. Although there are only a limited number of surveys measuring internal exposure received by mill workers, the indication is that significant radon daughter concentrations are usually not found. There exist a few exceptions in which the concentrations approach those experienced in underground mines, but with improved ventilation it is assumed that future exposure to radon daughters in uranium mills should be low. Projections to date indicate that total lung exposures in milling operations could be similar to that for mining.

Workers engaged in milling operations are also highly exposed to alpha radiation and are subject to additional lung cancers above the 1.0 - 1.2 excess lifetime cancers per 1000 Mwr/yr of nuclear power generation. In addition the annual results of lung disease and accidents must also be added.

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Population exposures

EPA has estimated the population weighted exposure from radon daughters arising from uranium mill tailings using two different models for atmospheric transport (7). The simplest model, which treats radon diffusion on the basis of gross meteorology, yields an annual exposure of 6.5×10^{-4} person-WL per curie/yr released. A more detailed meteorological model developed for EPA by National Oceanic and Atmospheric Administration (NOAA) has been used to calculate the exposure due to radon daughters from four release sites in the Western U.S. These exposures range from 4.2×10^{-4} to 7.6×10^{-4} person-WL per curie per year released, yielding an average of 5.6×10^{-4}. A population exposure due to radon daughters of 6×10^{-4} person-WL per curie released per year is used in this analysis. It is based on the assumption that exposure from the emitted radon and its daughters occur at seven-tenths of the equilibrium concentration. This average applies to the entire U.S. population. In 1974, EPA estimated the annual release from twenty-two known inactive uranium mill tailings piles as about 80,000 Ci per year. The population exposure from this release is estimated as

$$6 \times 10^{-4} \frac{\text{person-WL}}{\text{Ci/y}} \times 8 \times 10^{4} \text{ Ci/y} = 48 \text{ person-WL}$$

The individual exposures to persons working or residing near the point of release are of course substantially larger than the national average. Because the local population density is markedly different near various tailings piles, the regional impact from each should be considered on a site-specific basis. When it is arbitrarily assumed that tailings piles are located in a low-population area, 7.5 persons per square mile, the population exposure to a uniformly distributed local population is about 1×10^{-4}

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person-WL per curie/yr released so that regional health impact appears to be only one-sixth of that occurring nationally. However, a preliminary EPA analysis of the actual population distribution around tailings piles located at Salt Lake City, Utah, and Grand Junction, Colorado, indicates that the regional population exposures from these sources account for almost all the exposure.

In those cases where the local population density is high and the tailings pile large, the magnitude of regional health impact projections approach those for the national total from all inactive tailings piles. For example, the Vitro pile in Salt Lake City, which produces a large fraction (16%) of the total radon emissions in the U.S. from inactive piles, results in an exposure of about 100 person-working levels to the 800,000 persons who reside locally. For Grand Junction, Colorado, the estimated exposure to the regional population is about 40 person-working levels per year.

B. Uranium Hexafluoride Production

The yellowcake extracted from the ore in the milling process is shipped to conversion plants, where the U_3O_8 concentrate is converted into the volatile compound uranium hexafluoride (UF_6). The UF_6 is then used as feed to an enrichment facility. The total domestic commercial industry produces about 17,300 MT of uranium per year as UF_6, with a typical conversion plant having a capacity of 7000 MT of UF_6 annually. This capacity is sufficient to produce 24,000 MWe-yr of electric energy.

There are two different industrial processes involved in the production of UF_6. In the dry hydrofluor process the uranium concentrate is passed through successive reduction, hydrofluorination and fluorination steps

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followed by fractional distillation of the crude uranium hexafluoride to obtain a pure product. The second method begins with a wet chemical solvent extraction step to produce a highly purified uranium oxide feed prior to the reduction, hydrofluorination and fluorination steps. In this process, a flame reactor is used instead of a fluidized bed unit to carry out the fluorination step. Approximately equal quantities of UF_6 feed are produced by each method, although waste effluents differ somewhat between the two methods.

Radiological Effluents

In the dry hydrofluor process the radioactivity released is primarily in the gaseous and solid states, while the wet solvent process discharges radioactivity into liquid streams.

a.) Gaseous effluents: A minimal amount of radioactive effluents are released into the atmosphere from exhaust air as dust. The quantity of natural uranium emitted in this fashion from all processes associated with the wet procedure is approximately 100 mCi per year. The calculated concentration of natural uranium in the air at the site boundary is about 700 pCi/m^3. The total industry airborne emissions are estimated to be about 8 Ci for the period 1975-2000.

b.) Liquid effluents: Radioactivity in liquid effluents, originating primarily from natural uranium, has averaged less than 2 $\mu Ci/m^3$. The radionuclide concentration in the water retention pond of the wet solvent process would be about 1 mCi/m^3 of Ra 226 and lesser amounts of Th 230 and natural uranium. The radioactivity in a neutralized pond is usually found in the settled sludge, with only about 2% of its total activity present in the liquids. After evaporation, the remaining sludge is expected to be

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disposed of at licensed burial grounds or reprocessed at a mill to recover the uranium, with transfer of the waste material to the mill tailings pond.

The wet process UF_6 facility has a river adjacent to it, whose flow has been measured monthly. The flow would be expected to provide enough dilution of any radionuclides in it to reduce their concentration to below maximum permissable levels.

Estimated waterborne radiological emissions for all heavy elements (mainly U 238, U 234 and Th 234) from the projected UF_6 industry range from 340 Ci to about 451 Ci, depending on whether plutonium recycle is used or not.

c.) Solid Effluents. The primary source of solid radioactive wastes is the ash residue from the fluidized bed fluorinators formed during the dry hydrofluor process. The residue is packaged and consigned for burial at a licensed commercial disposal site. The principal constituent is Th 230 (18 Ci/yr) with about 3 Ci/yr of uranium isotopes in equilibrium with their daughters, and about 2 Ci/yr of Ra 226. Much smaller amounts of solid ash wastes are produced in the flame fluorination stage of the UF_6 wet solvent process. The total quantity of radioactive solids estimated to be emitted by the UF_6 industry over the period from 1975-2000 ranges from 21,000 Ci to 28,000 Ci.

Table 4.2.-2 summarizes the radiological effluents from hexafluoride production of both types, normalized to a model 1000 MWe-y LWR annual fuel requirement.

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TABLE 4.2.-2

Radioactive Effluents from UF_6 Production (curies)
per 1000 MWe LWR requirement/yr.

Gases Uranium	 0.003
Liquids Ra-226 TH 230 Uranium	 0.0034 0.0015 0.044
Solids (buried) other than high-level	 0.86

Occupational Exposure

Employees of the UF_6 portion of the uranium fuel cycle are exposed to external beta and gamma radiation, as well as to natural uranium and uranium daughters in the atmosphere. Domestic UF_6 plant operations have conducted plant measurement surveys, and their results indicate that external exposure to beta and gamma radiation averages about 0.5 rem/year, but most of this is from the beta component and thus does not apply to the whole body problem.

Internal body doses are the result of inhalation of air containing radionuclides in addition to penetrating external gamma radiation. An average whole body dose commitment per individual worker is expected to be about 0.2-rems/yr with critical organ dose commitments of about 1.5 rems to the lung and about 2.2 rems to the bone. These figures can be used to compute an integrated whole body dose commitment for the entire industry population over the period 1975-2000 of 3500 to 4400 person-rems.

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C. Enrichment

Enrichment of uranium is presently being carried out at three large government-owned and contracted gaseous diffusion plants, located at Oak Ridge, Tennessee, Paducah, Kentucky, and Portsmouth, Ohio. The total capacity of the three plants have an output which is sufficient to produce about 90,000 MWe-yr of electrical energy from LWRs. The federal government is currently planning to increase the capacities of the three plants by a factor of 2.5 to meet projected domestic and foreign demands. Conversion to the gas centrifuge method is being considered.

Radiological Effluents

Small amounts of uranium are released from the enrichment plants during normal operations in both gaseous and liquid forms. The bulk of the radioactive effluents are discharged to holding ponds as a liquid and then dispersed to streams, while a small portion of the effluents are released to the atmosphere. Releases from uranium enrichment, normalized to a 1000 MWe-yr model LWR annual fuel requirement is about 0.002 Ci/yr of uranium in gaseous forms and 0.01 Ci/yr of uranium in liquids.

Occupational Exposure

Personnel employed in the uranium enrichment industry will be exposed to small quantities of beta and gamma radiation, as well as radioactivity from airborne particles. Annual monitoring of personnel at the Oak Ridge Gaseous Diffusion Plant was made over the five-year period, 1970-1974. Exposure to gamma radiation has remained at about 50 mrem/year on the average, but the beta doses have declined sharply from 1970 to 1974 and now add little to the effective dose. Internal exposure can result from inhalation of radionuclides in the air. The level of the radionuclides does not exceed

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$5.5\ pCi/m^3$, which will produce an annual critical organ dose commitment of about 0.7 rems/individual.

Predictions for the year 2000 indicate that the occupational doses will not change significantly for the gaseous diffusion operations. For plants using the centrifuge procedure, however, the whole body occupational dose commitments are expected to increase because of the increased number of employees at these facilities.

D. Fuel Fabrication

The enriched uranium hexafluoride is used as feed material in the fabrication of fuel for LWRs. It is converted to UO_2 powder, which is formed into pellets, sintered and then loaded and sealed into zircaloy or stainless steel tubes. The process that is currently being used to produce the fuel is a wet ammonium diuranate (ADU) process. The present fuel fabrication industry consists of 9 commercial operations, each performing either a specific step of the fabrication process, or the entire process.

Radiological Effluents

Very small quantities of airborne radionuclides are emitted from fabrication operations. The annual atmospheric releases for a plant with an annual throughput of 1000 MT of uranium are estimated to be about 0.008 Ci/yr. About one-third of the uranium losses are liquid and are discharged to a waste lagoon. Liquid releases include uranium and thorium 234 (which grows back after being separated from the uranium products at the milling plant). The solid wastes are made up of CaF_2 containing small amounts of uranium, and account for almost two-thirds of the uranium losses. These solid

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effluents are normally buried within the plant site, or may be sent to licensed commercial burial grounds. The radiological effluents from a fabrication plant normalized to a model 1000 MWe-yr LWR annual fuel requirement are about 0.002 Ci/yr of uranium in gas form, 0.013 Ci/yr of uranium and thorium 234 in liquids, and 0.23 Ci of uranium in solids.

The estimated radioactive emissions from the fuel fabrication industry over the period 1975-2000 are predicted at 1.3 curies from airborne effluents and 3.0 curies from liquid effluents if no recycle is implemented, and a slight reduction if both uranium and plutonium are recycled.

Occupational Exposure

Personnel employed by the fuel fabrication industry are exposed to external radiation, as well as to internal radiation from airborne radionuclides. These exposures are estimated to produce an annual whole body dose commitment of about 0.20 rem per individual, in addition to a critical organ dose commitment of about 10 rems to the lung.

E. Mixed Oxide (MOX) Fuel Fabrication

If plutonium recycle is incorporated into the uranium fuel cycle, then fabrication of mixed oxide fuel from uranium and recovered plutonium will be required. It is estimated that 8 model plants employing 24,000 persons would be needed for this to occur by the year 2000. It is assumed that plutonium recycle will not begin before the year 1981.

Radiological effluents

Estimates of radiological effluents emitted from a MOX fabrication industry are about 0.034 Ci of uranium, plutonium and americium in the gas phase, and about 0.007 Ci of the same mixture as liquid waste.

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Occupational exposure

Employees of a MOX fuel fabrication plant may receive an average annual whole body dose commitment of about 1.2 rems from external radiation and 0.2 rems from internal radiation.

F. Reprocessing

Spent fuel from uranium-fueled LWRs can be reprocessed to recover usable fissionable material (both uranium and plutonium). The fuel elements removed from the reactor still contain about one-quarter of the original U 235, in addition to Pu 239 produced from the absorption of a neutron by U 238. If plutonium recycle is implemented, a portion of the original plutonium content will also remain in the spent fuel. The recovered uranium is converted to UF_6, shipped to enrichment plants and eventually recycled to nuclear reactors. The recovered plutonium can be converted to PuO_2 and then mixed with UO_2 for recycle in reactors. The reprocessing operation involves the separation of the fission products from the uranium and plutonium. The fissionable uranium and plutonium are recovered as purified nitrate solutions. Radioactive wastes must be converted into forms suitable for transfer to Federal waste repositories, which will be the ultimate confinement location for various types of radioactive wastes.

Three commercial nuclear fuel separation facilities have been built in the U.S., none of which are in operation at the present time. Reprocessing and recycle have been controversial subjects because of the potential health problems which can result from the widespread use of plutonium, and because plutonium can be used in the production of nuclear explosives.

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Radiological Effluents

After the fuel rods with the spent fuel are removed from the reactor, they are stored for about 150 days to allow significant reduction of the radioactivity of the shorter half-life radionuclides. Despite this reduction in radioactivity, however, large quantities of natural and reactor-generated radioactive materials are still found in fuel rods at reprocessing. A significant portion of the radioactive effluents from the entire fuel cycle is encountered in the reprocessing stage.

The Nuclear Fuel Services Reprocessing Plant (NFS) was in operation from 1966 to 1972, and was then shut down for alterations and expansion. The plant released to the atmosphere all the Kr 85 and C 14, about 60% of the H 3, and very small quantities of radioiodine and other fission products present in the spent fuel. Additional tritium and other radioactive materials were released to streams as liquid effluents. The following data in Table 4.2.-3 show the effluents discharged from the NFS plant, normalized to a 1000 MWe-yr or uranium processed.

TABLE 4.2.-3

Effluents Discharged from Nuclear Fuel Services Reprocessing Plant

Radionuclide	Ci/1000 MWe-yr
Gases	
Krypton 85	340,000
Tritium (H^3)	220,000
Carbon 14	10
Iodine 129	0.003
Iodine 131	0.06
Other fission products	0.9
Actinides	0.004
Liquid	
Tritium (H^3)	4,000
Ruthenium 106	4

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If plutonium is recycled in LWRs over the period from 1975 to 2000, the amount of MOX reprocessed is expected to total about 11% of the total fuel reprocessed, mostly to be processed in plants not yet designed. The recycling of plutonium will not affect the amount of fuel reprocessed, but will primarily change the mixture of radioactive effluents.

Determination of the population or occupational exposures from fuel reprocessing is difficult at this time. From the nature of the isotopes released at NFS (Table 4.2.-3) exposures to the general population would be largely to krypton 85, tritium and transuranic actinides, and thus would affect mainly people living near the plants. Estimates of occupational exposures are generally low, but experience with the reprocessing plant in England, which has been operating commercially for more than a decade, shows average occupational exposures of about 1.3 rads/yr.

4.3 TRANSPORTATION

Throughout the nuclear cycle, transportation of potentially hazardous radioactive materials is required, and for this reason the total number of miles of transport is higher than for coal. In general, however, the volume of material transported is much less than for the coal cycle, but the potential hazard to the general public or the workers is greater than for coal, especially if the containment of these materials is breached. In addition, there is the potential for injury due to accidents even if the containment of activity is maintained.

The most significant source of exposure is from spent fuel or reprocessed fission products after the fuel is used in energy production.

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The risks from spent fuel will predominate in the short run, but in the long run transportation of the reprocessed waste will probably lead to greater population risks than for spent fuel. Transportation of these highly radioactive sources is carried out in lead-shielded casks designed to withstand significant impact. Shipment is primarily by truck, but some by rail. To the present, we can only speculate on the health impact on the general population of transportation of nuclear materials, except from gamma ray exposures in transit, which are less than 1 mrem per person, or negligible in relation to natural background. An individual who stood next to a cask for several minutes could receive about 1 mrem/2 min. Exposures of the general population from accidental breaching of the containment casks could be much higher or not, depending on where the accident occurred, but it is difficult to forecast these kinds of exposures.

Occupational radiation exposures are relatively low. Estimates of exposure for the truck drivers are about 15 mrem for a 500-mile haul, including time spent working adjacent to the cask. Spent fuel haulage is estimated to require about 20 shipments per year per 1000 MWe, or a total of 10,000 miles per year per nominal plant. Thus at the present rate exposures of drivers should be well within acceptable limits, unless relatively few drivers handle the entire nuclear industry. If plutonium recycle is undertaken, some additional exposure would occur, particularly from transport of the solidified high-level waste to a final repository. Finally, risks to the drivers from road accidents exist, but they are likely to be much lower per shipment than for coal shipments because the progress of the shipment will be very closely supervised.

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The above discussion has assumed that shipments of ore or unirradiated fuel contribute negligible population or worker exposures. Low-level waste shipments may contribute some occupational exposures because of the larger volume and greater number of shipments required per 1000 MWe/yr.

An accident occurred in Colorado in 1977 in which several tons of yellowcake (U_3O_8) were spilled. This incident did not produce a significant general exposure to radiation, but it did emphasize the importance of plans for clean-up operations from a major spill, especially if the material had a much higher radiation risk than yellowcake.

The total exposure from transportation of nuclear materials is three person-rem to the total population and 1 person-rem to exposed workers per 1000 MWe/yr.

4.4 NUCLEAR POWER PLANTS

Within the reactor radioactive materials are generated as a result of the fissioning of uranium, and by neutron absorption in the coolant and structural materials. The products of uranium fission include a large number of elements in both their stable and radioactive forms. In the operation of nuclear reactors, a small amount of these created radioactive materials are expelled to the atmosphere or to nearby waters, but the majority are contained within fuel rods. After a period of operation, the spent fuel rods must be removed from the reactor, stored for a cooling period and then shipped to a fuel reprocessing plant. The amount

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of radioactive effluents released to the environment at the reactor site depends on several factors, such as the type and size of the reactor, reactor design, percent of fuel failures, and the control measured used.

Almost all of the current nuclear power plants in operation in the U.S. today employ light water reactors to generate power. There are two types of LWRs - the Boiling Water Reactor (BWR) which allows the water in the reactor to boil, and the Pressurized Water Reactor (PWR) where the water inside the reactor is prevented from boiling by pressures of about 150 times atmospheric pressure. These differences in processes result in different types and quantities of radioactive materials being emitted from PWRs and BWRs.

Radiological Effluents

Radionuclides may enter the environment through either the gaseous or liquid effluent streams. The airborne effluents consist of fission noble gases (krypton and xenon isotopes), activation gases (Ar 41, C 14, N 16, S 35), tritium, radioactive halogens and particulates. In the liquid effluents are found tritium, fission products and activated corrosion products.

a.) Fission noble gases. Several isotopes of the noble gases Kr and Xe are created by fission in the nuclear fuel. The amount and composition of Kr and Xe escaping to the collant and eventually to the environment depends on the rate of their escape and the hold-up time prior to release. In PWRs the gas volume buildup in the collant (water flowing through the core) is relatively slow, and therefore gases can be held up for a relatively long time (more than 30 days) before being released. A 30-day delay would reduce all the short-lived radionuclides to an insignificant level and

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only Kr 85 and Xe 133 would be released in any measurable quantities. The gas production rate in the BWR collant, however, requires continuous removal of non-condensable gases and, because of its large volume, the time between gas removal and release must be shorter. The current hold-up time for krypton from BWRs is about one day. In addition to Kr 85, Xe 133 and Xe 135 comprise an important part of the noble gas effluents from BWRs. The total emission of noble gases from PWRs during 1976 varied from a few up to 15,000 Ci/1000 MWe-yr, whereas from BWRs the range was from 30,000 to more than 1,000,000 Ci/1000 MWe-yr.

b.) Tritium. Tritium is produced in both BWRs and PWRs from tertiary fission, but most is produced as an activation product in the primary coolant. Approximately 90% of the tritium is released as a liquid effluent and the remainder in the form of a gaseous water vapor. About 1000 Ci/1000 MWe-yr was released from PWRs and 100 Ci/1000 MWe-yr from BWRs.

c.) Radioiodine. Several isotopes of iodine are produced in reactors by fission and by decay of other fission products. I 131 with a half-life of 8 days is the isotope which is of main concern from an environmental standpoint. It is released as both a liquid and gaseous effluent. The measured releases of this radioactive halogen vary from several millicuries to up to 100 curies per 1000 MWe-yr of power production.

d.) Particulates in airborne effluents. Particulates can arise either directly or as decay products of fission noble gases. Almost all of the particulates are prevented from escaping to the atmosphere by high efficiency particulate air filters. Only the smallest particles can escape, which results in very low levels of particulate activity. It is estimated that in 1974 from PWRs there was 0.5 Ci per 1000 MWe-yr emitted, and 1.1 Ci per 1000 MWe-yr from BWRs in the U.S.

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e.) Radionuclides in liquid effluents. Tritium and I 131 comprise the major portion of the liquid effluents from reactors, but there are other radionuclides which can be found in significant quantities. These include a number of fission and activation corrosion products, such as cesium 137, cesium 134, cobalt 58, cobalt 60, chromium 51, magnesium 54, molybdenum 99, and iron 55.

The U.S. Nuclear Regulatory Commission annually presents measured data on radioactive materials in effluents from licensed commercial LWR power plants. EPA has studied time trends of releases, which indicate the fluctuations which have occurred in the release of radioactive effluents over a 5-year time span from 1970 to 1975. There is also great variability in releases from one reactor to another of the same type.

Occupational Radiation Exposure

Table 4.4.-1 is a summary of the number of annual whole body exposures to workers at LWRs for the years 1969 through 1977. The total number of individuals monitored for radiation exposure has increased steadily, as has the number of personnel receiving measurable exposure. The percent of individuals with measurable dose receiving exposures exceeding 5 rems has remained about 1% over recent years.

An average of 669 persons per reactor received measurable exposure at commercial LWRs in 1976, a number which represents a progressive increase during the past several years. Since 1972 the average exposure to workers has remained about 0.7-0.8 rem/yr. The number of persons receiving exposures in excess of the short-term limits established by 10 CFR 20 at commercial reactors is also reported for the years 1971 through 1977 in Table 4.4.-1. It is apparent from Table 4.4.-1 that both in terms of short-term

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TABLE 4.4.-1

PERSONNEL RADIATION EXPOSURE FOR LIGHT WATER REACTORS LICENSED BY U.S. NUCLEAR REGULATORY COMMISSION

SUMMARY OF ANNUAL WHOLE BODY EXPOSURE BY INCREMENT

YEAR	NUMBER OF INDIVIDUALS													NUMBER OF OVER-EXPOSURES
		EXPOSURE INCREMENT - REM												
	TOTAL MONITORED	NOT MEASURABLE	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	>10	
1969	2854	2607			144	70	26	5	2	0	0	0	0	
1970	7518	6953			184	175	92	102	11	1	0	0	0	
1971	10269	9660			328	146	107	17	11	0	0	0	0	2
1972	15730	14783			536	205	114	47	23	10	6	6	0	16
1973	35918	20717	10249	2449	1585	432	237	117	71	38	16	7	0	19
1974	38379	20240	13455	2491	1375	470	226	86	30	6	0	0	0	43
1975	45659	20188	18277	3892	1903	707	426	169	60	24	12	0	1	14
1976	61151	25704	26636	4880	2354	789	487	188	70	26	11	5	1	20
1977	70904	27671	33252	6174	2838	1130	569	141	66	36	21	6	0	27

SOURCES: 1969-1976: NUREG-0323 "Occupational Radiation Exposure at Light Water Cooled Power Reactors 1976"
1977: NUREG-0463 "Occupational Radiation Exposure" Tenth Annual Report 1977

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overexposures (most of which result in partial body exposure from inhaled radionuclides, generally of a few rads), or in terms of average annual exposures, the current standards are frequently exceeded.

The data shown in Table 4.4.-1 are for all reactors operating in each year. Analysis by specific reactor shows that while the average dose per exposed worker for all reactors is about 0.75 rem/yr, for individual reactors the averages show a wide range. In 1976, the range of average exposures for BWRs was 0.4 to 2.2 rems, while for PWRs the range was 0.2 to 1.7 rems. In part this range reflects the number of years the reactor has been in operation, the older plants having higher exposures to the workers, but the large range shows that control of worker exposure is much less effective in some plants than in others.

Within a particular plant there is also variability in radiation exposure by the type of work carried out. Evidence indicates that maintenance workers and the health physicists responsible for radiation protection have higher individual doses than operating personnel in the reactors. The significance of this variation is that simply giving an average annual exposure cannot indicate the potential risk to individual workers in a facility, although it is a useful datum for analysis of total societal cost of nuclear operation. The consistency of the pattern of exposure shows that definition of individual risk by job category and by reactor can be done, but there remains the question of the appropriate level to assume, especially when projecting to the year 2000.

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4.5 WASTE MANAGEMENT AND DISPOSAL

The disposal of radioactive wastes is one of the most controversial aspects of the uranium fuel cycle. The major problem is presented by the highly radioactive fission products created in the nuclear reactors, as well as the plutonium and other heavy elements produced there.

The Nuclear Regulatory Commission has grouped the wastes from the nuclear fuel cycle into six major categories. Four of these arise from either uranium-only recycle or both uranium and plutonium recycle: high-level wastes, transuranium-contaminated wastes, non-transuranium-contaminated wastes (usually called low-level wastes), and contaminated facilities and large equipment. In addition, the uranium fuel cycles give rise to two other classes or wastes: spent fuel from the no-recycle option and unused plutonium from the uranium-recycle option.

High-level wastes (HLW) are produced at fuel reprocessing plants, and contain most of the highly radioactive fission products separated from fissile material. These wastes are perhaps the most difficult to handle in terms of containment because of the need for shielding and heat dissipation. According to Appendix F of 10 CFR 50, HLW must be converted into solids within 5 years after being generated, which then must be transferred to a Federal repository for storage within an additional 5 years. The fission products that are found in HLW include the transplutonium elements and about 0.5% of the uranium and plutonium that were originally in the spent fuels.

Transuranic wastes are determined by their concentration of transuranic elements (i.e., a minimum of 10 nCi/g being emitted from elements with atomic numbers larger than 92). Transuranic wastes are generated primarily

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after fuel reprocessing operations. Waste materials included in this category are solidified liquids, cladding hulls and other fuel hardware, and general trash.

Non-transuranic low-level wastes are defined as any radioactive waste material which contains less than the minimum amount of transuranium elements (as defined in the previous paragraph). These materials are contaminated with fission products with relatively short half-lives, the maximum being around 30 years.

Contaminated equipment and large facilities are taken out of service by a procedure termed decommissioning, which varies depending on the type of facility. Some of the actions involved in decommissioning include equipment removal, removal of contaminated concrete, chemical scrubbing and removal of cell liners.

Wastes containing radioactive isotopes are produced at each segment of the uranium fuel cycle. Much of the waste is low-level and can be dealt with by storage in licensed repositories, but the principal problem is potential exposure to the general public from solidified high-level wastes and the transuranics. The bulk volume of this waste is relatively low, about 10 m^3 of spent fuel per 1000 MWe-yr for current reactors, and less for solidified fission products from reprocessing. Long-term storage in a location from which negligible activity can reach human contact is required.

At the present time, the plan most carefully researched for long-term disposal of HLW calls for placement in geologically stable salt beds. The Department of Energy is in the process of selecting a suitable site for this disposal. If one assumes that a repository for HLW or spent fuel can be built which will adequately cope with the long-lived radionuclides generated

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in the production of nuclear fuel, the environmental impact of nuclear waste management should be relatively small, but at present this problem is unresolved.

4.6 SUMMARY OF EXPOSURES

The assessment of probable future health and disease impacts from the ORBES nuclear scenario (2c) is based upon a number of assumptions. First, that current impacts are reasonably accurate. This statement may be challenged in view of the ongoing research, particularly that concerned with the effect of low-level radiation. Secondly, that both scientific and public pressure will continue to demand improved control and prevention procedures to reduce the current level of impacts. Dr. Radford developed risk and damage estimates on the foundation of current and anticipated normal operations of the nuclear fuel cycle in electricity generation. No attempt has been made to quantitate risks due to accidental releases, such as could occur as a result of a criticality accident or reactor malfunction. So far, reactor accidents have not included a break in the reactor primary containment system. A fact which has meant that the exposure from these accidents to the general population has been low. However, the Three Mile Island, Pennsylvania accident, at the time of writing, is not over (decontamination is expected to take a number of years) and the final assessment is as yet to be completed. In particular, the total psychological, social and economic consequences have to be assessed and their health impacts remain to be evaluated.

Based upon available information it is our estimate that the projected 33 nuclear units, each 1000 MWe to be sited according to Scenario 2c would produce the following health impacts in the year 2000.

General population: a rate of 0.028-0.048 total incident lifetime cancer

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cases per 1000 MWe-yr power production without plutonium recycle, or a rate of 0.11-0.31 cancer cases with plutonium recycle, would result in 0.9-1.6 or 3.6-10.2 cases, respectively. Occupational impacts: 96-106 cases of lifetime cancer, accidental trauma and chronic lung disease -- of which 12-13 would be fatalities.

The literature survey conducted by ORBES (8) indicated that for all functions of the nuclear cycle at this time the total number of deaths per 1000 MWe reactor year ranges from 0.1 to 0.85. Assuming that the current rates would prevail this would mean 3.3 to 28.05 deaths per year for the projected 33 reactors in Scenario 2c in the year 2000.

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5. HEALTH ASPECTS OF POWER TRANSMISSION

The following discussion concerning the health aspects of electric power transmission was prepared by Dr. Edward P. Radford as part of his study of the impact on human health from the coal and nuclear fuel cycles and other technologies associated with electric power generation and transmission (1). The reader is also referred to the paper presented by Richard D. Phillips, Ph.D., at the Symposium on Energy and Human Health: Human Costs of Electric Power Generation (2).

Introduction

Power transmission is common to all kinds of electric power generation and fuel types. Electricity is transmitted by alternating current at both high and low voltages, high voltages being used for energy transfer for long distances from a generating source to a population center. Lower voltages are used within the population center to distribute electricity to individual consumers. The effects of electricity carried in wires are electric and magnetic fields, and corona effect around the transmission lines. In considering health effects, risks occur to the general public from exposure to the above fields, as well as accidental injury or death from broken or falling transmission lines as a result of wind or ice damage, earthquakes, etc. Occupational hazards also exist from working closer to the lines, not only to the electromagnetic fields but also from direct contact with high-voltage terminals or other low-resistance pathways.

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The transmission of electricity from a remote generating source to load centers is accomplished by means of Extremely High Voltage (EHV) lines. EHV levels vary from 230-800 kilovolts (kV). There are advantages to the use of higher voltages within this range. For example, one 765 kV line has the equivalent load carrying capability of five 345 kV lines and its right-of-way requires 145 feet less. With the growth of electric power consumption the trend has been to use higher voltage transmission. As of January 1, 1970, the circuit miles of AC EHV lines existing in the United States are as in Table 5.-1.

TABLE 5.-1

CIRCUIT MILES OF HIGH VOLTAGE TRANSMISSION LINES IN U.S., 1970

Voltage Levels (kV)	Approx. Circuit Miles
230	1420
287	1020
345	14070
500	6840
700 (765)	66

Accurate measurements of the induced currents and power absorbed by a human body from the electromagnetic fields around power lines have been difficult to obtain. Electric field measurements provide the basis for calculating the induced human body current from transmission lines. Practical measurements with a dosimeter show much lower electric field exposure than that calculated on the basis of the maximum field in a work area. Power frequency currents are induced in the body of people who are in the presence of electric field produced by high voltage transmission lines and substations. Over flat ground the electric field is vertical and uniform over the dimensions of a human being (3). The electric field is not uniform close to non-flat boundaries like vehicles, towers, trees, bushes, and transformers.

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The induction field or uniform electric field produced in a human being whose head is 1.76 meters above ground and is walking occasionally through a 20 kV/m field is 5.75 kV/m and corresponds to a space potential of 10 kV at the center of the head and the induced current is about 35 microamperes (μA). The body current perception level is about 1000 μA and is larger than the calculated total induced current in either a man on the ground or a lineman. The electric field recognition level and corona (ozone) forming level are 236 kV/m and 1968 kV/m respectively (4).

Environmental Mortality and Morbidity

Electrical accidents not directly related to linemen working in the transmission industry account for no more than 4% of all fatal accidents and 0.4% of all non-fatal accidents. Statistics for 1962 submitted to the International Symposium on Electrical Accidents showed that of 1118 electrical fatalities, 40% involved high voltages. Of the low voltage fatalities, 43% were industrial, 17% were agricultural, and 39% were domestic. Most HV accidents are occupationally related to electrical generation, transmission, or distribution; while more than half of the low voltage deaths occur during use of portable electrical equipment. Thus the exposure of the general public to injury from transmission line failures is very low.

Reviews of the biological effects of high voltage electric fields have been published. Four studies on short-term exposures to electrical fields involved the medical treatment experience of people living within 25 meters of a transmission line, the experience of farm workers on 18 farms traversed by a 765 kV line, and a physiologic state study involving lineworkers intermittently exposed to intense electric fields during maintenance work.

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No immediate, acute, or permanent effects were found; however, only 2 of these studies looked at long-term exposure(5).

In contrast, studies on workers exposed to electric fields in Soviet and Spanish high-voltage switchyards report effects such as excitability, headaches, drowsiness, fatigue, and nausea, but these effects may be related more to acoustical noise in the switchyard environment.

No immediate or acute effects were noted in laboratory animals exposed to electric fields. A small reduction in weight gain was observed in the progeny of mice exposed to intense fields (100 kV/m), and there was evidence of behavioral changes. Cell-mediated immunity changes were reported for rodents exposed to intense fields up to 100 kV/m (5).

Corona Effects

Corona is an electrical discharge occurring at the surface of a transmission line conductor when the electric field intensity at the surface of the conductor exceeds the breakdown strength of the air. Corona effects associated with transmission lines could generate ozone and nitrogen oxides. According to one study, emissions due to a 765 kV line would result in concentrations of 2 to 3 ppb of ozone not to be exceeded more than one hour per year. Ozone is believed to produce adverse health effects at about 100 ppb, but the effects of exposure to 2-3 ppb over a long period of time are unknown. On a linear dose-response hypothesis the effects should be negligible. Nitrogen oxide would be at about the same concentration as ozone, also considerably below concentrations at which any effects would occur.

On the basis of the above data, the conclusion seems warranted that health effects to the general public from electric transmission are not

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yet demonstrated, and in any case are likely to be negligible in relation to the hazards from parts of the electric power generating system and the fuel cycles on which it depends.

Occupational Risks

Injury: Persons employed in electrical generation, transmission, and distribution are exposed to additional hazards as well as the normal work exposure of falls, lifting, etc. Many electrical accidents involve contact with A.C. 50 or 60 Hertz currents and most high-voltage accidents are occupationally related. Since linemen working on high and low voltage distribution equipment are working at elevated height, many electrical accidents cause severe injuries as a shock causes the body to involuntarily react and the worker falls from a pylon.

The various effects of accidental contact with electric currents include asphyxia from respiratory arrest caused when the electric current passes through the head. Very few of these accidents are fatal, since the head is not a common path for the current to take. Ventricular fibrillation occurs less when the current is over several amperes, so victims of HV accidents often survive. Finally, secondary effects, such as angina electrica, are clinically undistinguishable from angina pectoris, but clear up after a few months; chromoproteinuria and renal function disturbances and various neurological sequelae have been described (6).

Analysis of the injury and illness rates for the electrical industry in 1974 showed no difference from industrial experience as a whole, but in 1976 the death rate for all industries was 14 per 100,000 workers, while for Transportation and Public Utilities was 31 per 100,000. How much of this excess was related to transmission-line workers is not clear.

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In a study done by the Society of Actuaries in 1967, mortality ratios and extra deaths were calculated for occupations considered substandard by most companies for either life insurance or accidental death benefits; other occupations were included if there was reason to expect mortality somewhat above that for standard risks. Based on U.S. Bureau of Labor Statistics data for 1963 on-job occupational deaths, the on-job accidental rate for employed persons is 0.15 per 1000. The Standardized Mortality Ratio for violent deaths among transmission workers was 243 for non-climbing workers, but 425 for climbing workers. Thus the excess mortality for climbing linemen is about 0.27 per 1000. On the assumption that serious injuries could be four times the mortality, total injury would be about 1 per 1000 workers/yr.

To determine possible long-term health effects of electric fields, a medical follow-up study of high voltage linemen working in AC electric fields over a period of nine years was carried out. No disease states which could be in any way related to HV line exposure were found. Examinations consisted of complete medical history, physical, hemotological and blood chemistry studies, thyroid test, kidney and liver function tests, electrocardiograms, electroencephalograms, hearing test, x-rays, sperm count, and psychiatric evaluation. This is relatively short exposure, however, and the end points studied were non-specific.

It is difficult to convert occupational risks from injuries to a nominal plant requirement, but from Bureau of Labor Statistics about 100 line workers are required per 1000 MWe generation plant. On this basis, the risk per 1000 MWe/YR is about 0.1 serious injury per year per nominal plant.

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